Radiation Characterization Measurements at the Advanced Photon Source

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Advanced Photon Source

Radiation Characterization Measurements at the APS

10 CFR 835 (Subpart E)

Monitoring of individuals and areas shall be performed to ;

1. **Demonstrate compliance with the regulations**
2. **Document radiological conditions**
3. **Detect changes in radiological conditions**
4. **Detect gradual buildup of radioactive material**
5. **Verify the effectiveness of engineering and process controls in reducing the radiation exposure.**
6. **Identify and control potential sources of individual exposure**

Radiation Characterization Measurements at the APS Accelerators

- Measurement of Photon Dose with High Dose Dosimetry Techniques (Radiochromic Films)
- Measurement of Neutron Fluence online with good photon-neutron discrimination
- Measurement of Residual Activity of Accelerator Components
- MCNPX Calculations for Comparison

Measurement of Photon Dose in the Storage Ring (Radiochromic Films)

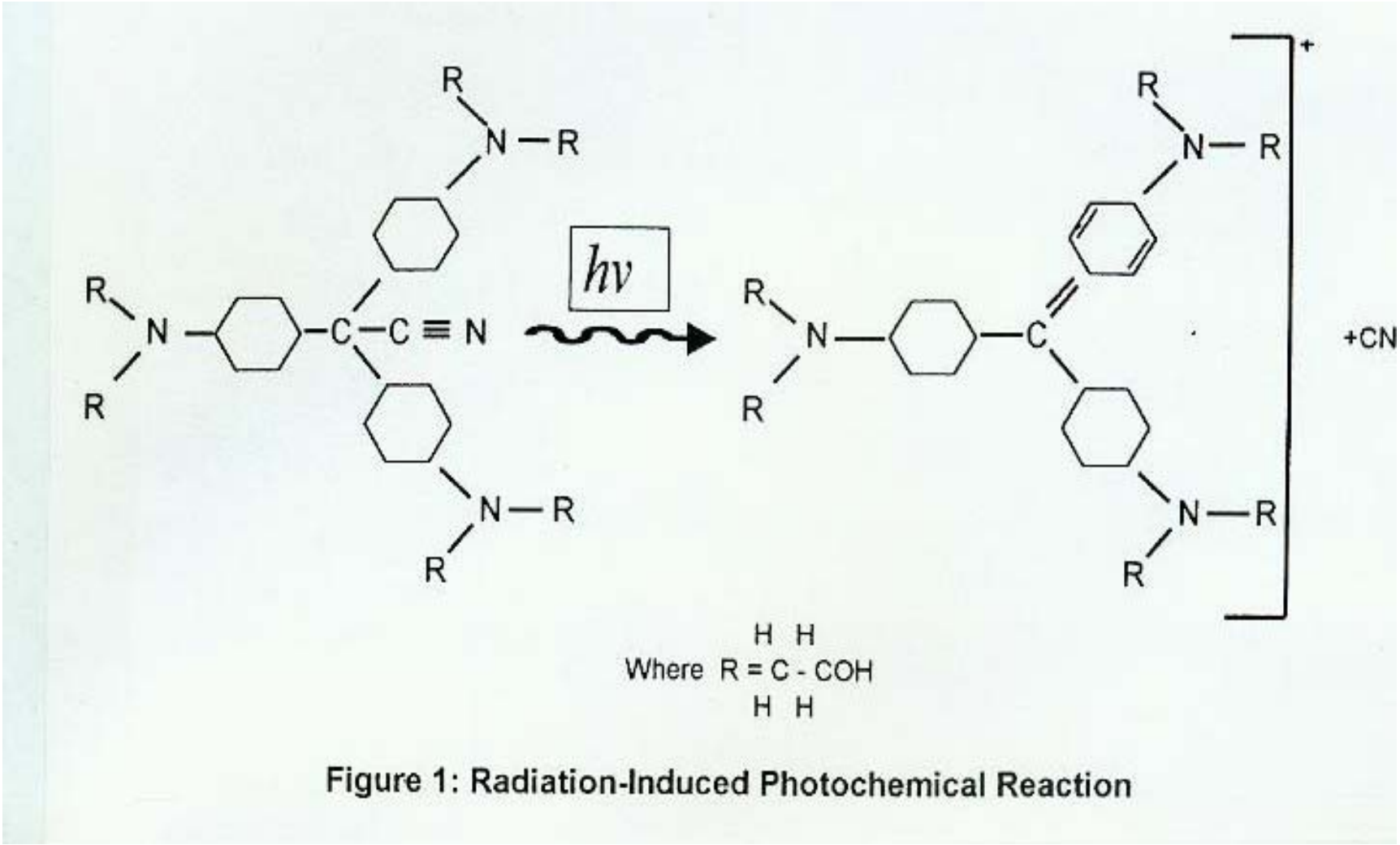
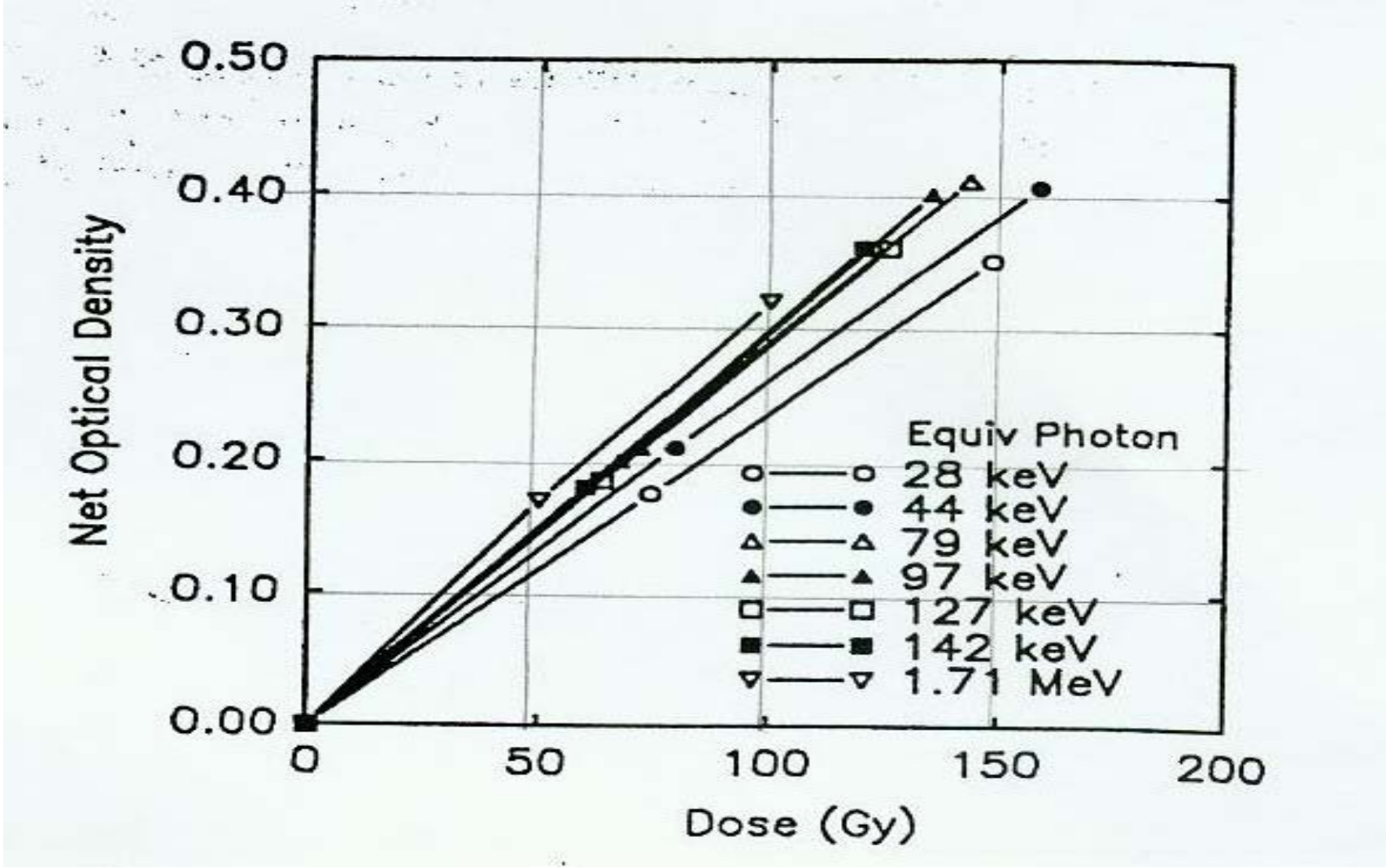


Figure 1: Radiation-Induced Photochemical Reaction

Measurement of Photon Dose in the Storage Ring (Radiochromic Films)



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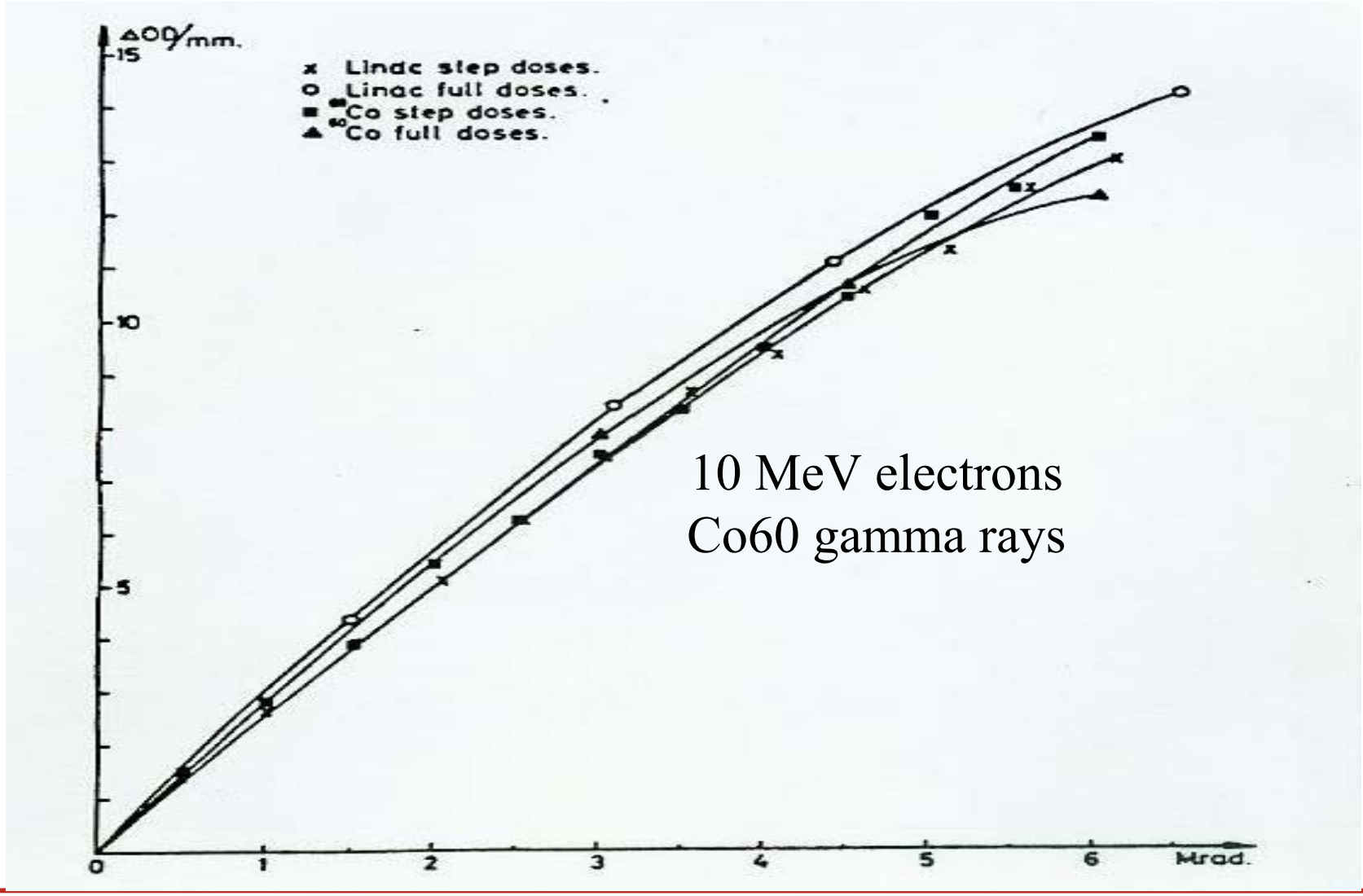
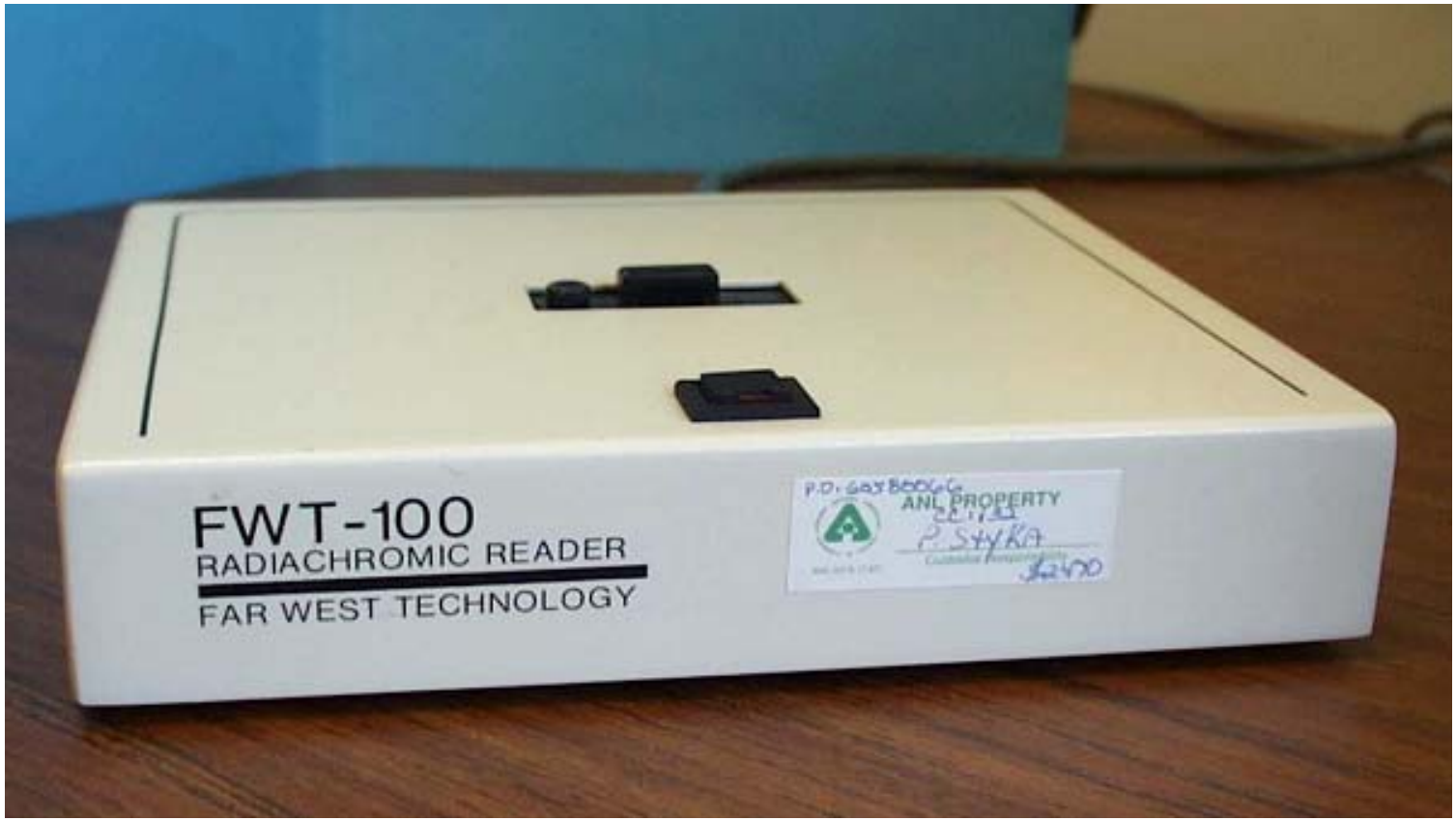


Radiachromic Dosimetry Equipment



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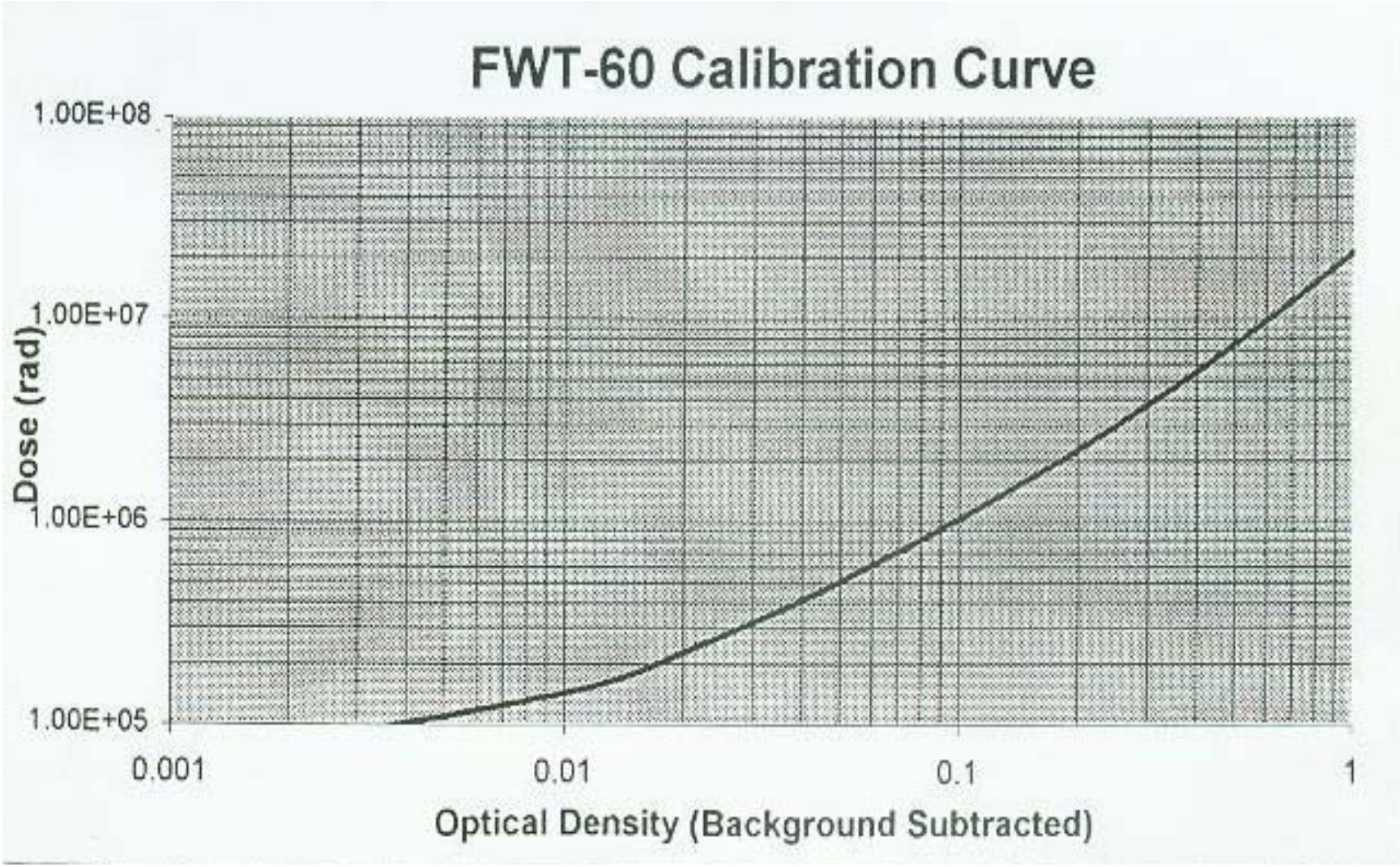

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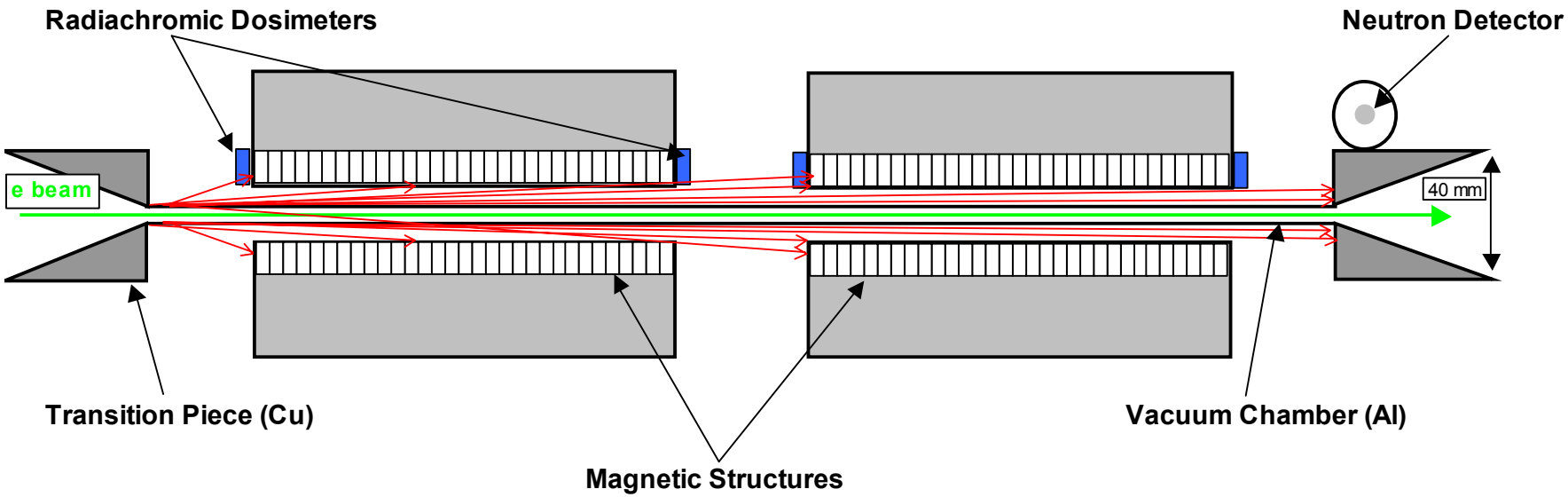
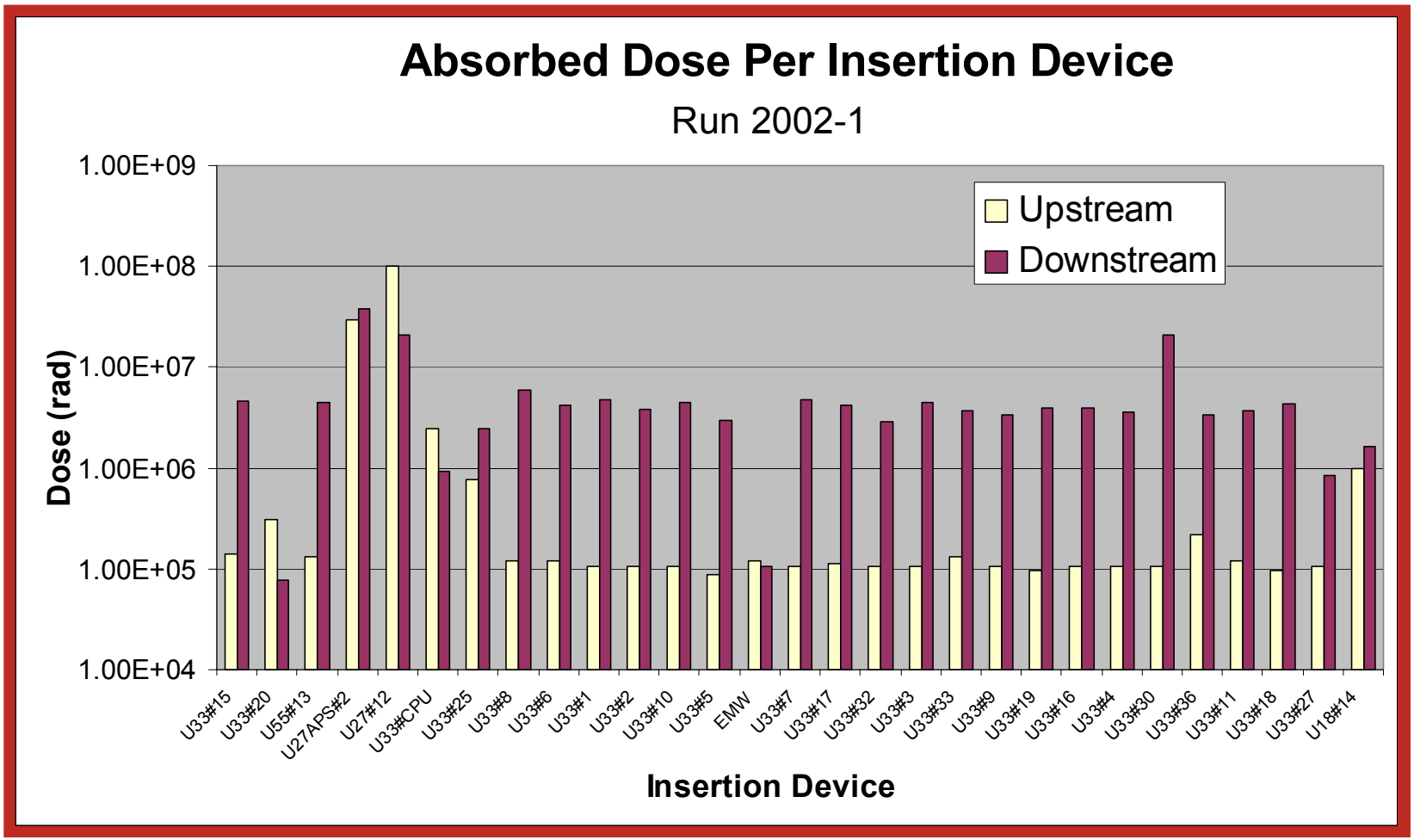
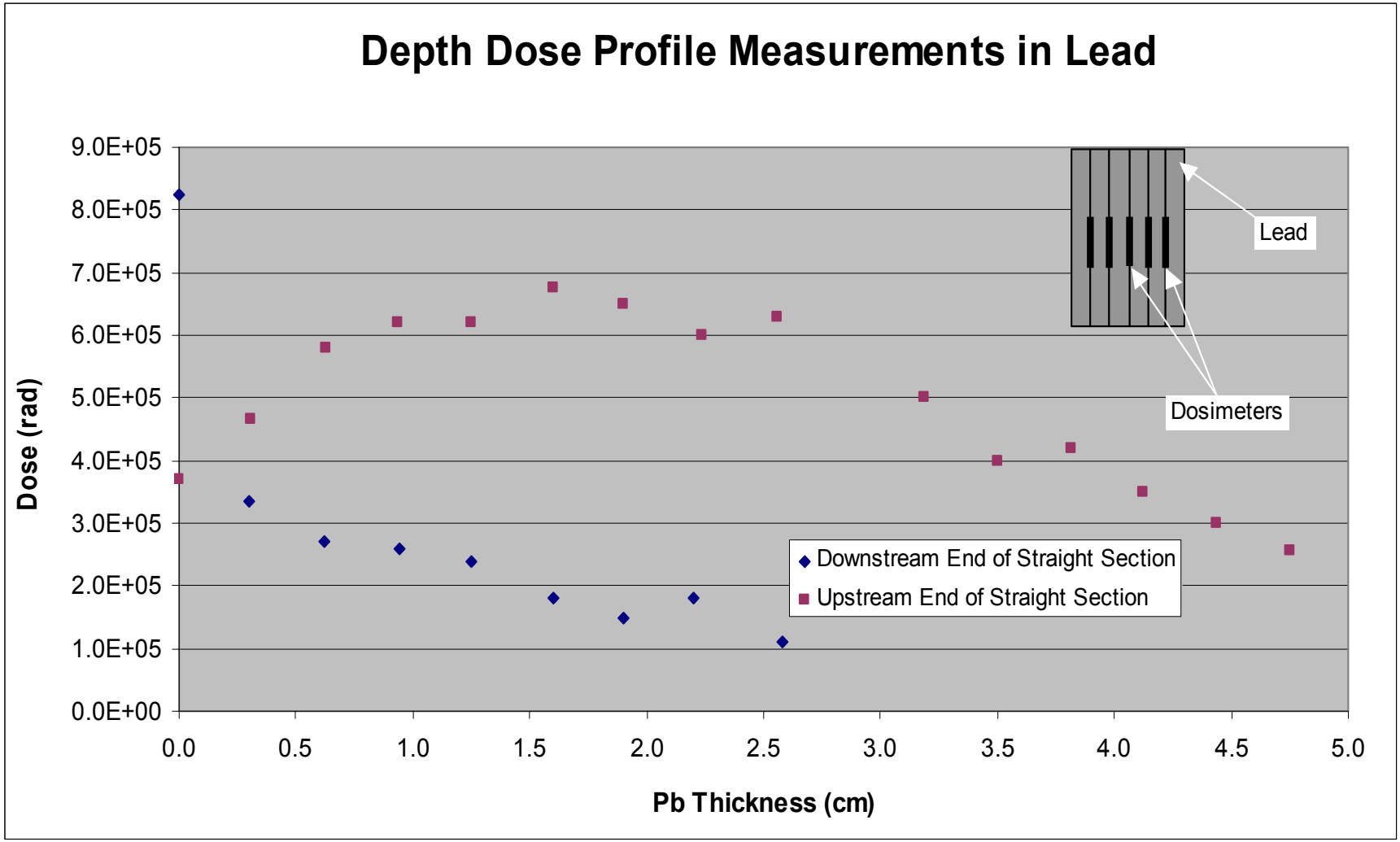


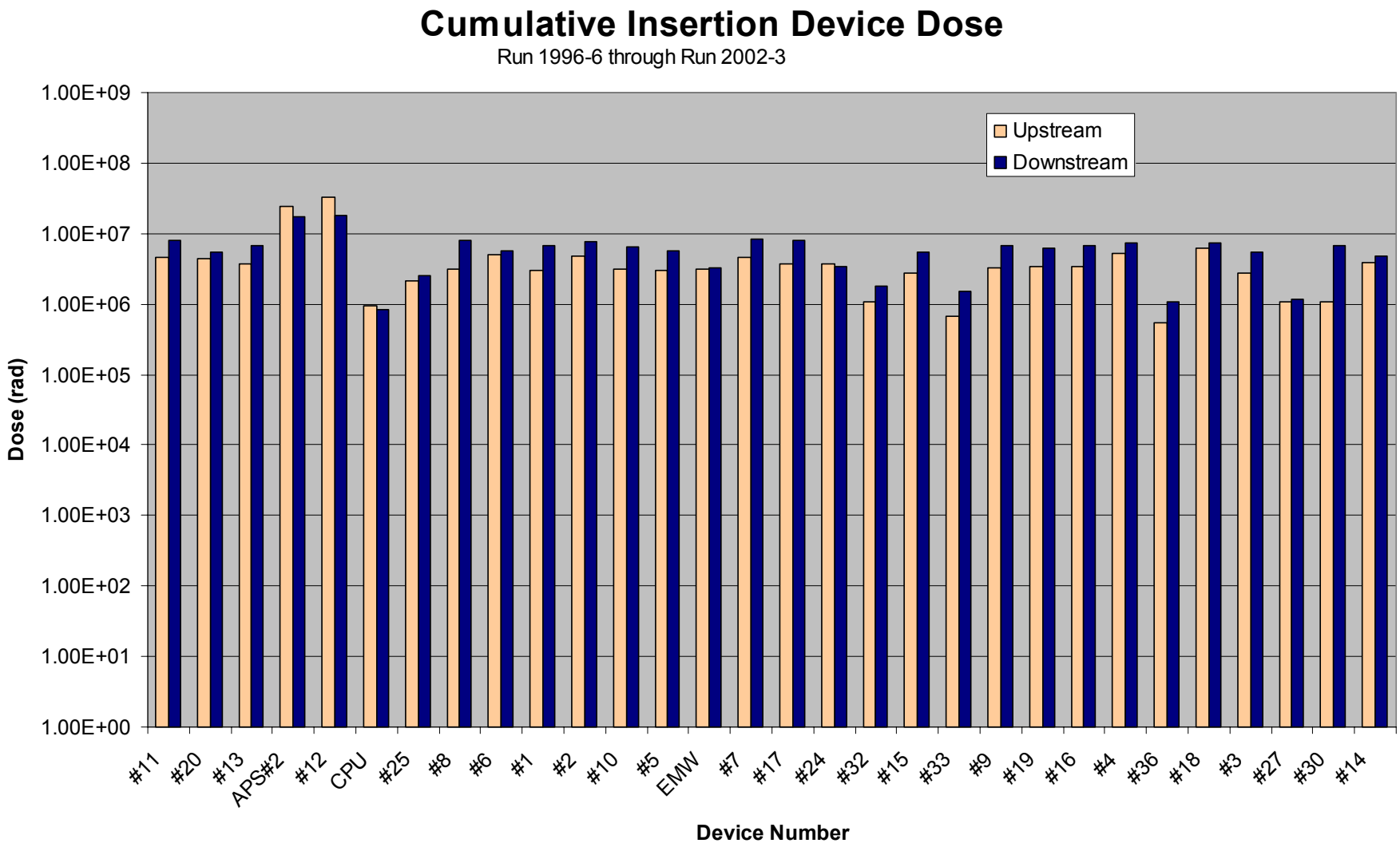
Measurement of Photon Dose
Radiochromic Film Results



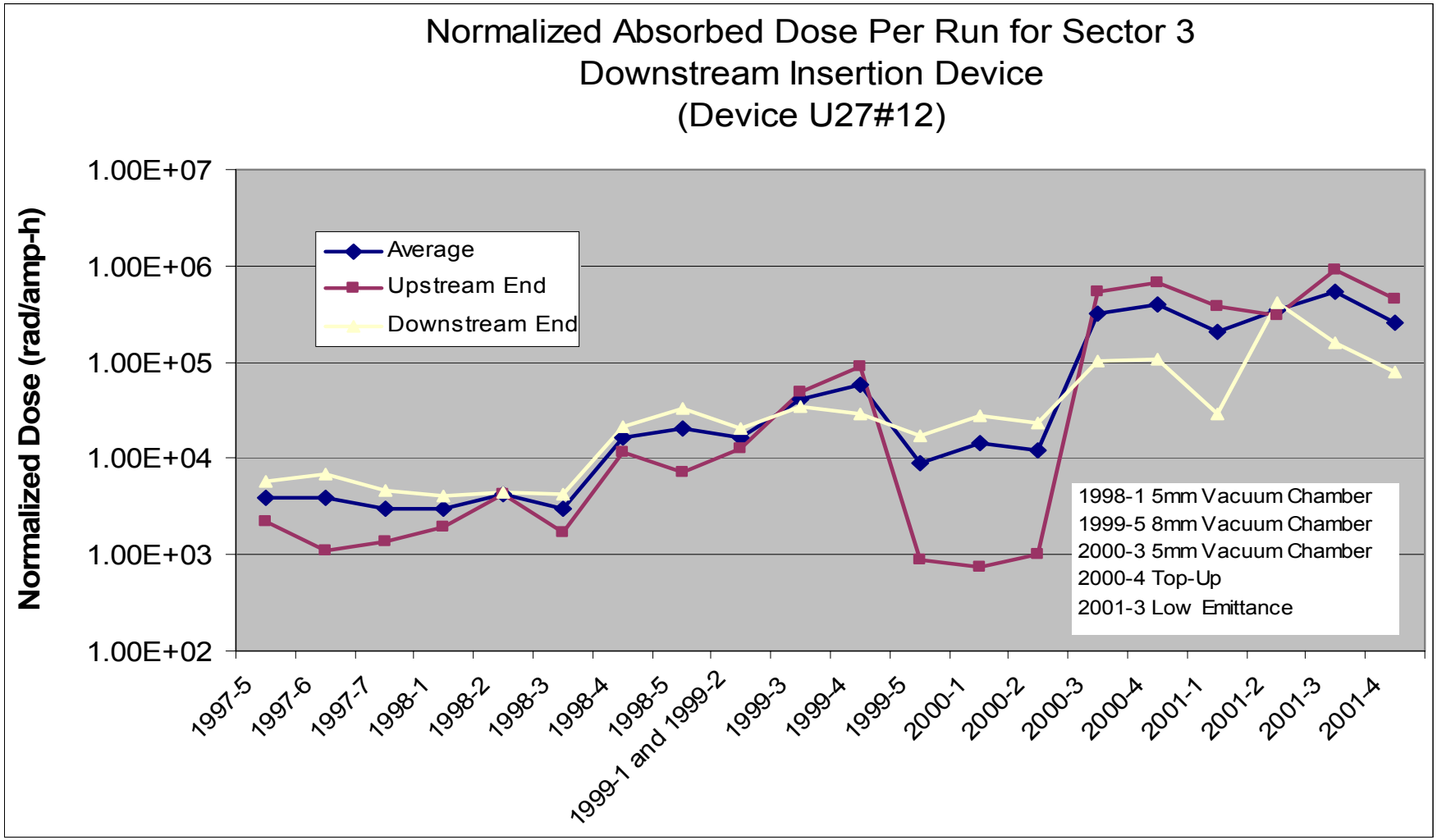
Measurement of Photon Dose Radiochromic Film Results



Measurement of Photon Dose
Radiochromic Film Results



Measurement of Photon Dose Radiochromic Film Results



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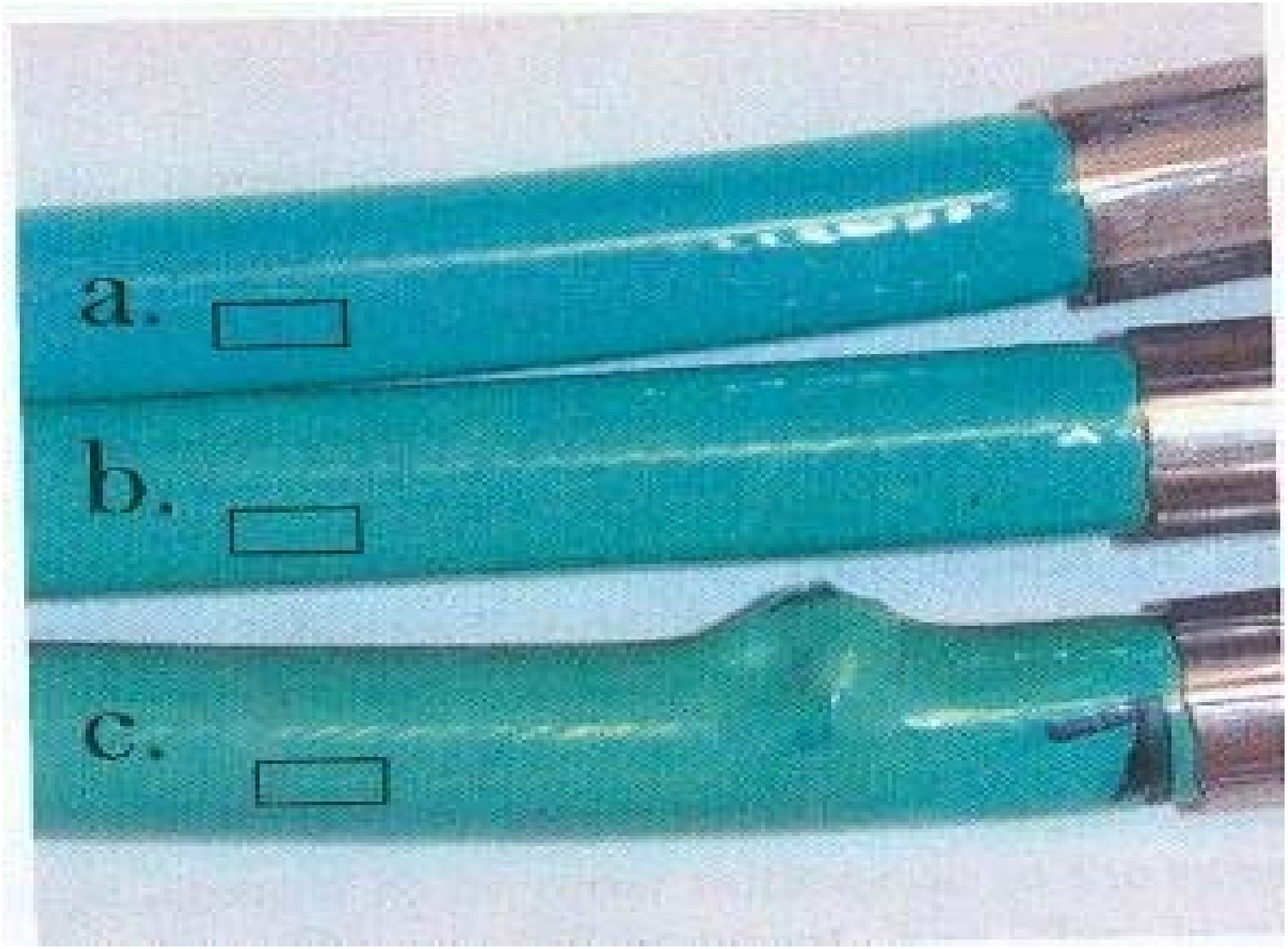
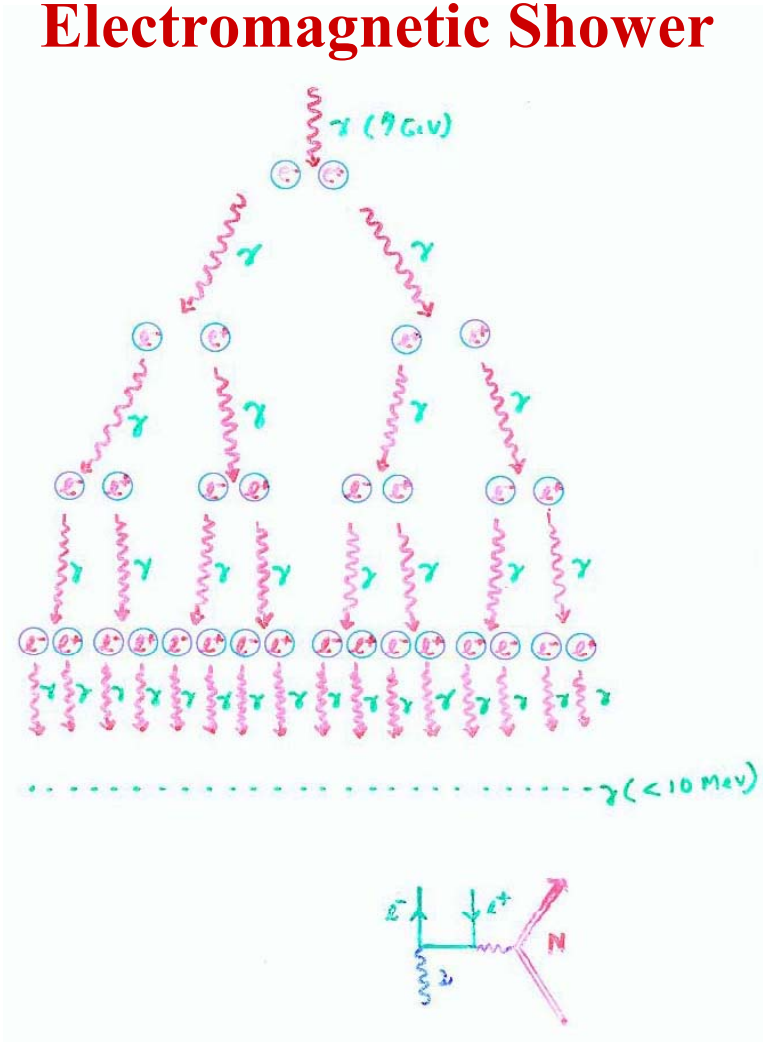


Measurement of Photon Dose Summary

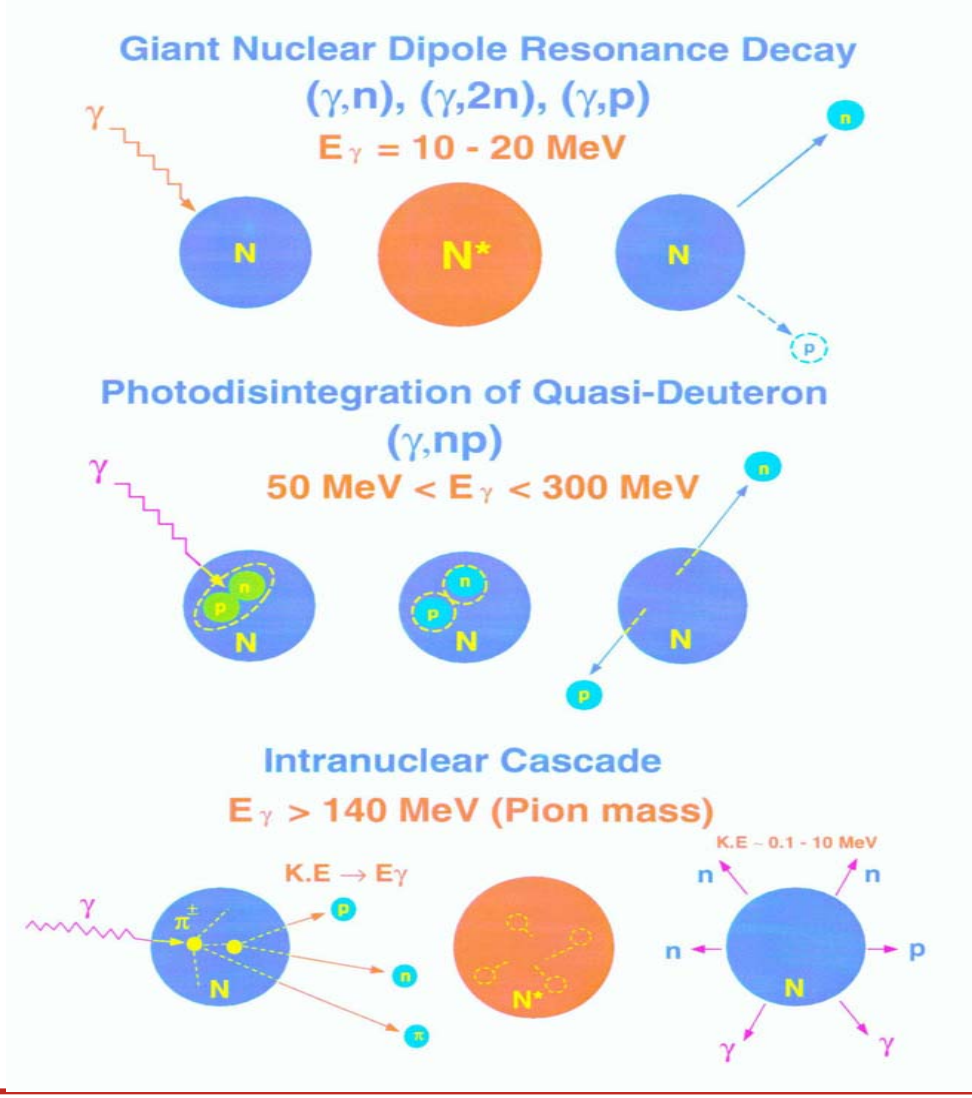
- Measurement of photon dose provides valuable information on the source term
- Dose at beamloss locations provide information on beam loss scenarios
- Radiation damage to the accelerator components can be correlated with the dose data
- Radiochromic films is a cost effective choice for high dose measurements in the storage ring

Measurement of Neutron Fluence in the Storage Ring

Electromagnetic Shower



Measurement of Neutron Fluence in the Storage Ring



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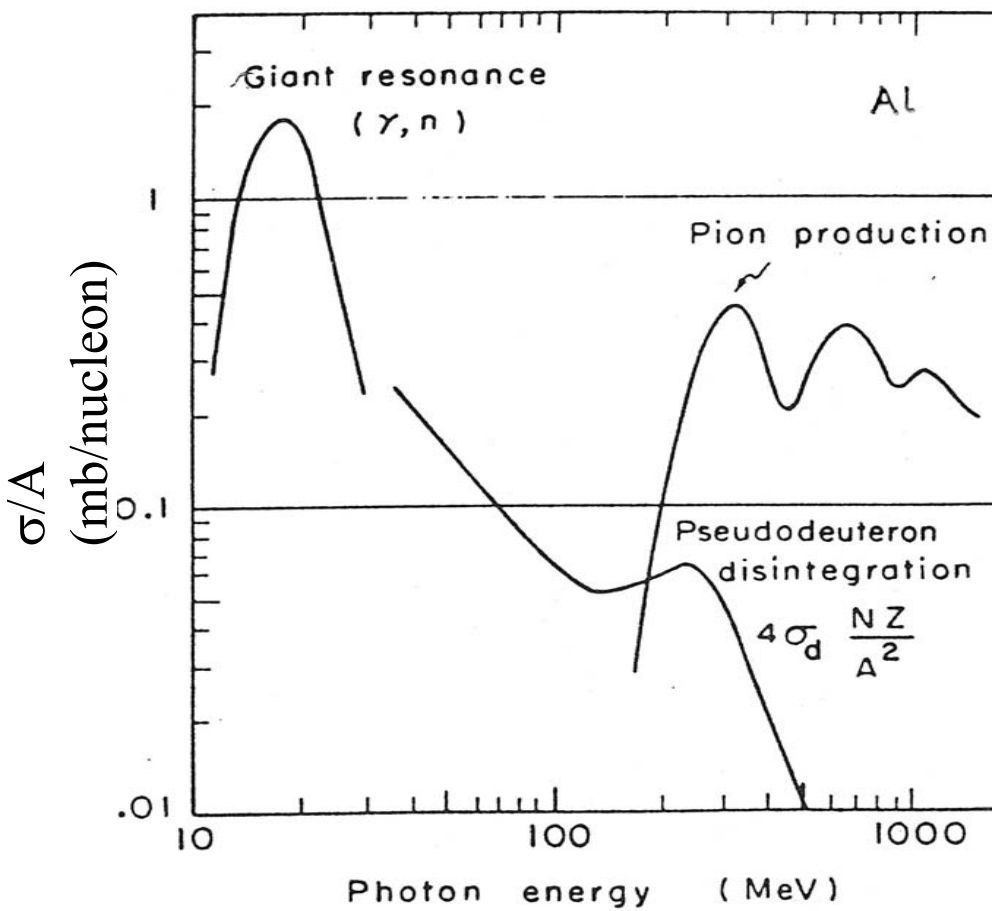
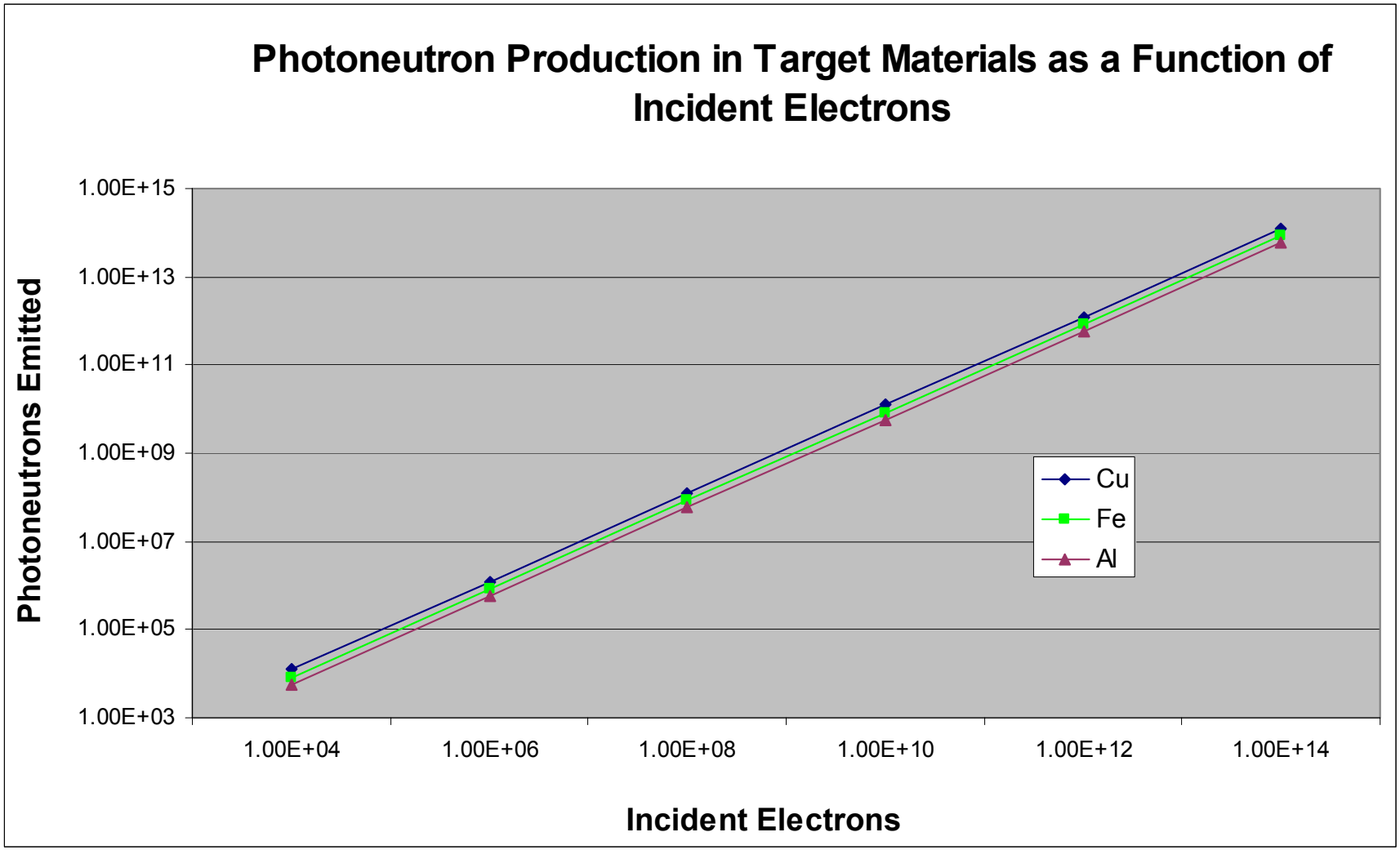
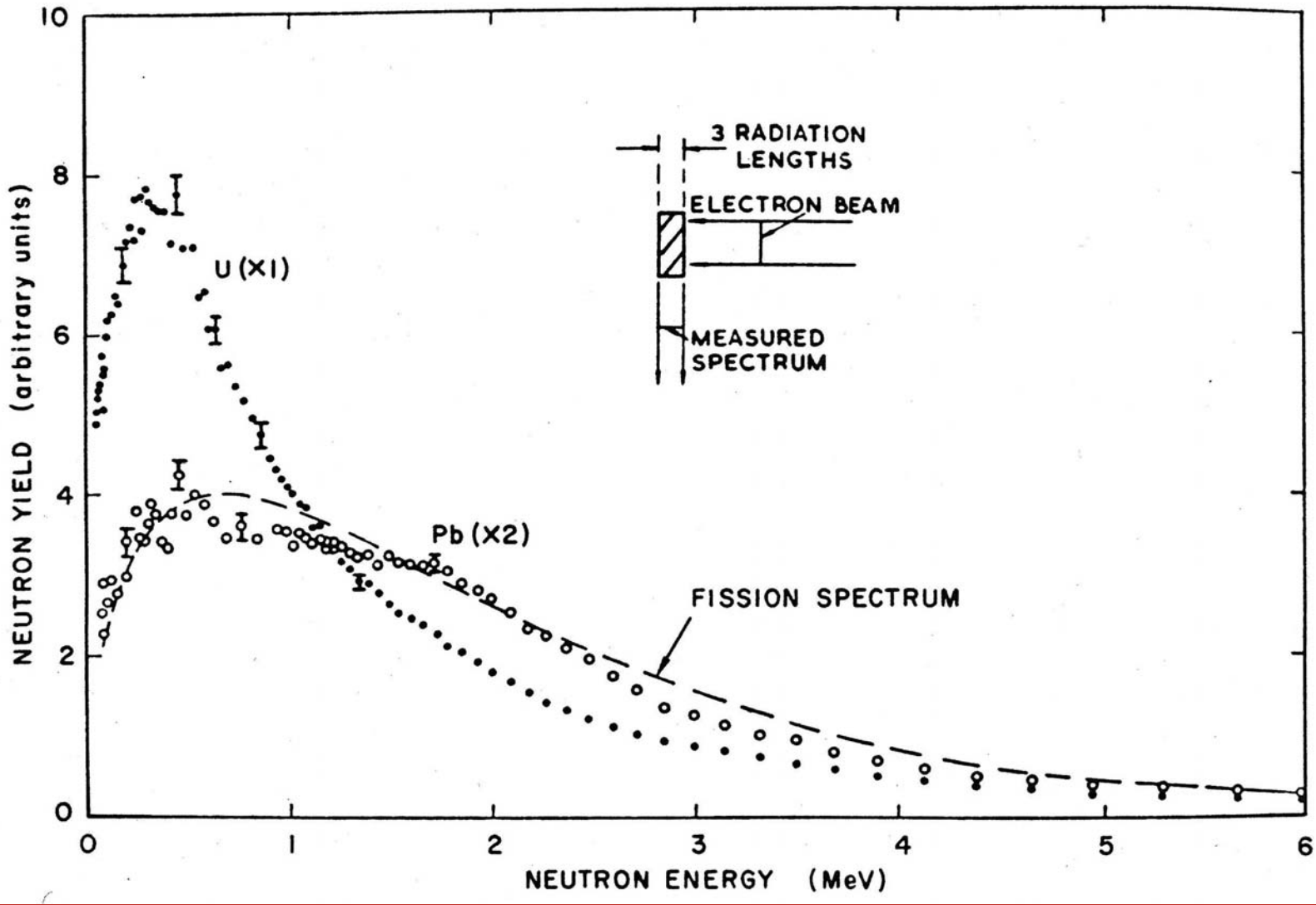


Measurement of Neutron Fluence in the Storage Ring (Neutron Yield)



Measurement of Neutron Fluence
Photoneutron Spectra

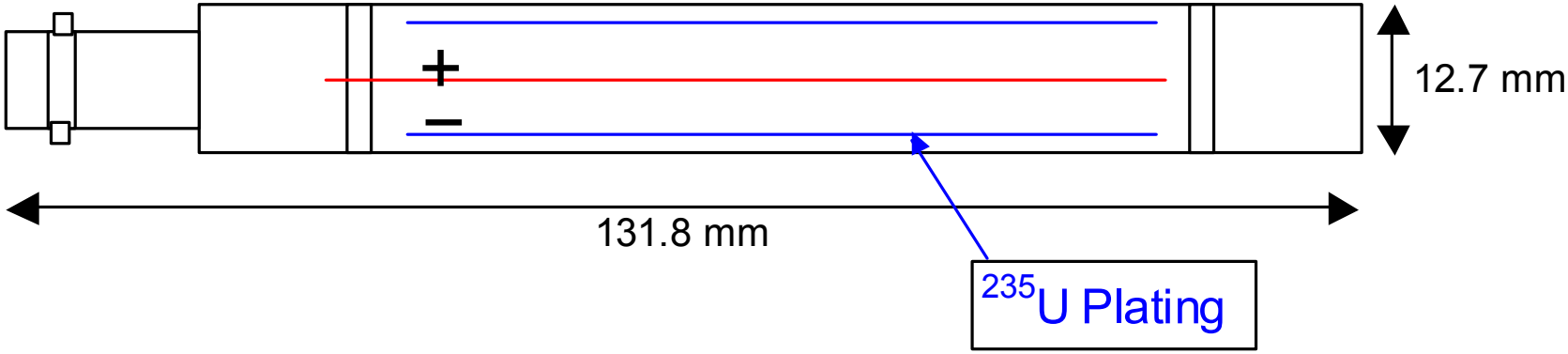


Neutron Fluence Measurements in the APS Storage Ring

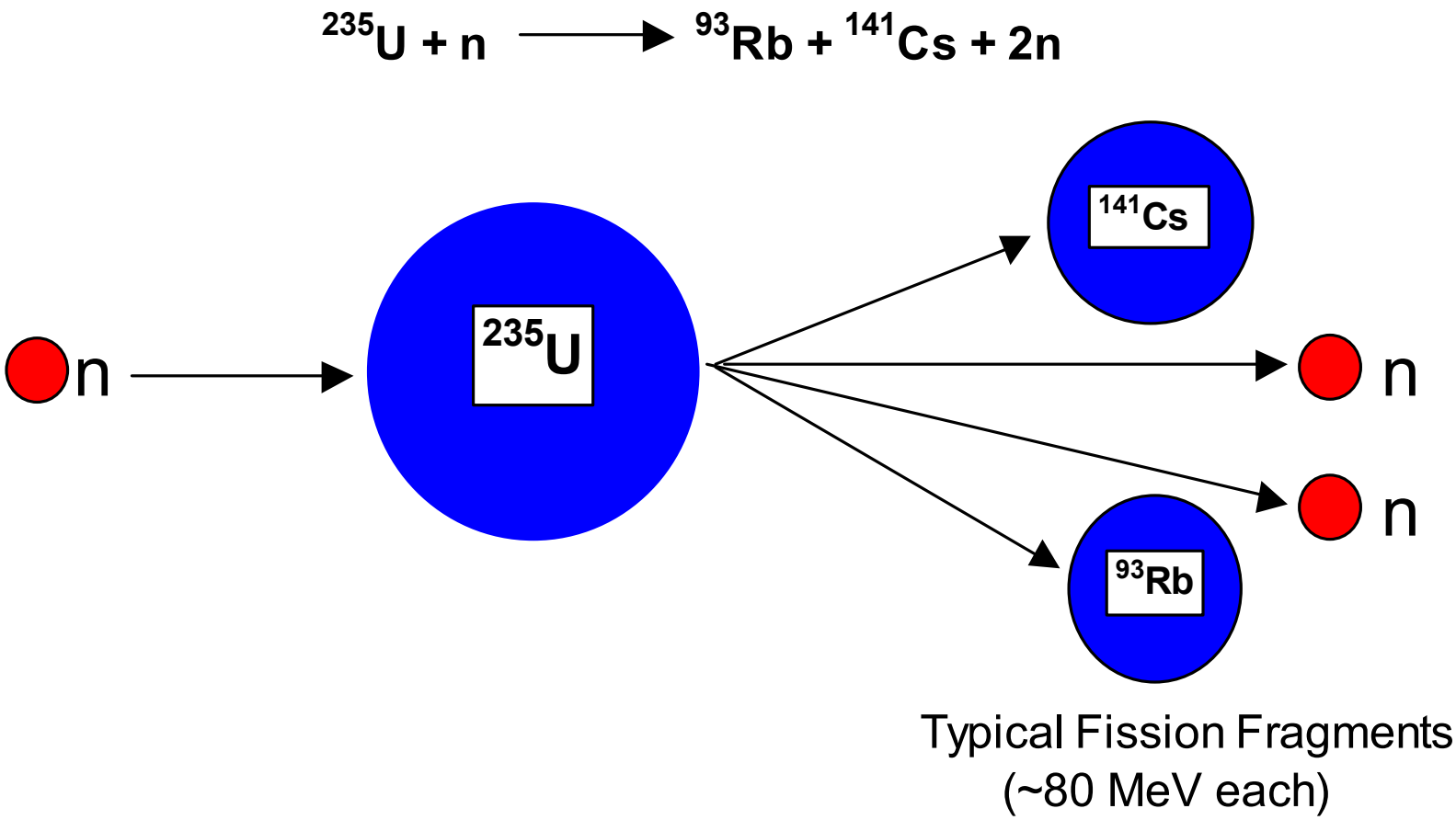
- Require a detector with very high photon-neutron descrimination

- Require high neutron detection efficiency
  - ^{235}U Fission Detector
  - MOSFET Detectors
  - Bubble Detectors

Neutron Fluence Measurements in the Storage Ring
^{235}U Fission Detector



Typical Neutron-Induced Fission Reaction



Fission Cross Section of Uranium Isotopes (^{235}U and ^{238}U)

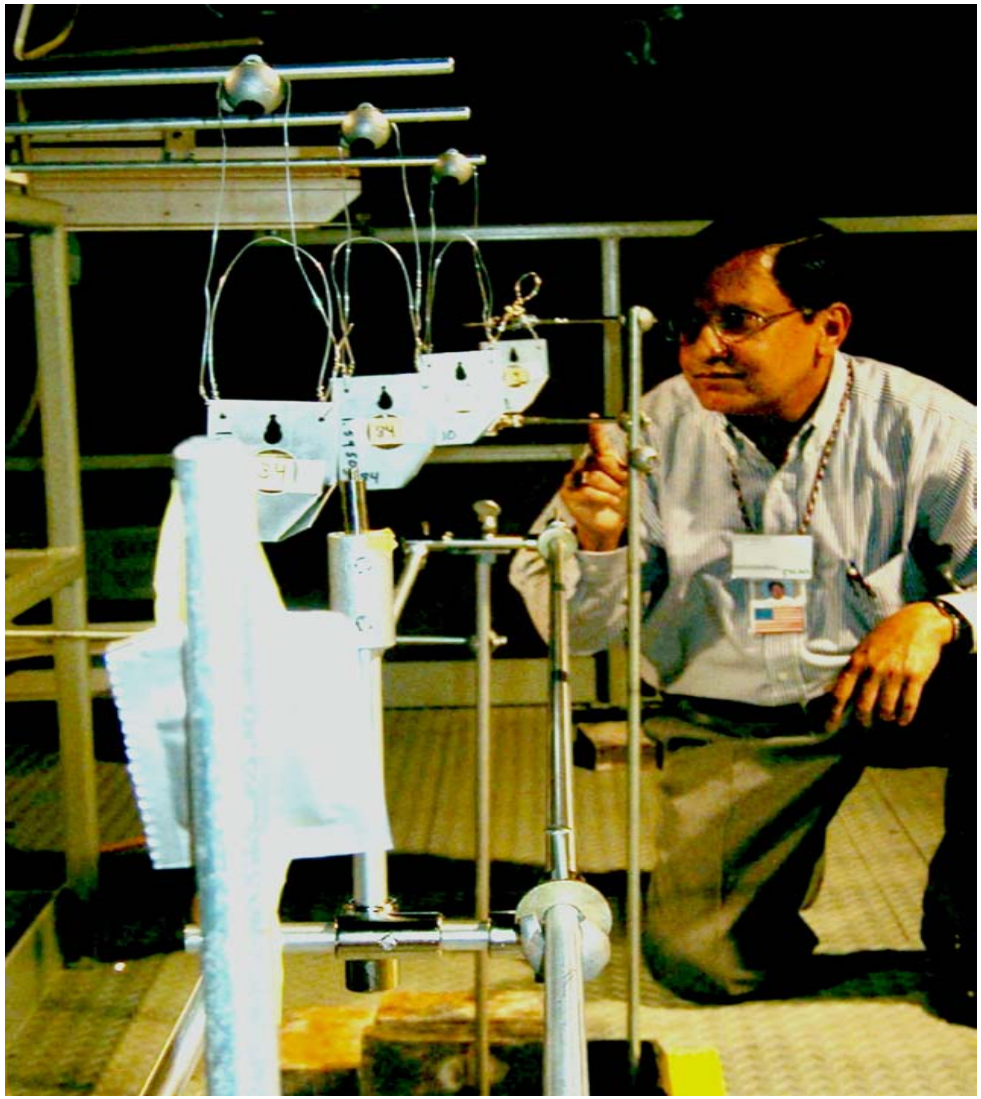
Particle / Radiation	Energy	Cross Section (barns) ^{235}U	^{238}U
Thermal Neutrons	~25 meV	582 b	0.0 b
Fast Neutrons	~1-2 MeV	1.2 b	0.6 b
Photons	>5.3 MeV	3-30 mb	3-30 mb

Neutron Fluence Measurements in the Storage Ring
^{235}U Fission Detector

Calibration of the Fission Detector with ^{252}Cf Neutron Source Spectrum

- Measure count-to-flux conversion factors for the detector-moderator configuration
- Optimize the moderator thickness to maximize efficiency

Calibration of the Fission Detector with ^{252}Cf Neutron Source Spectrum



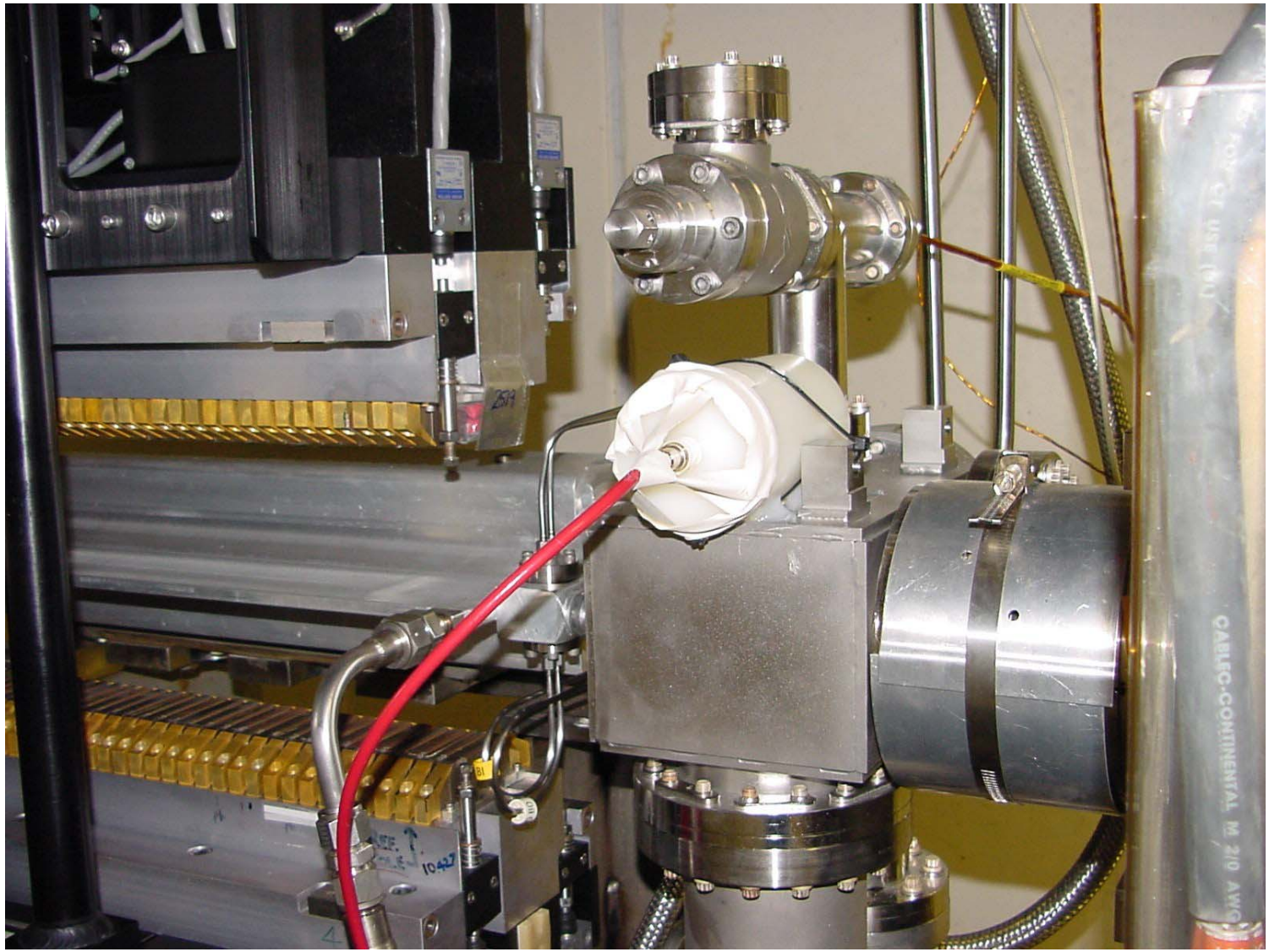
Calibration Results for Detector-Moderator Configuration
^{252}Cf Source – Gold Foil Activation Measurements

Source-Detector Distance (cm) (5 cm Sleeve)	Fluence rate from Au foil (n. $cm^{-2}.s^{-1}$)	Count rate ($c.s^{-1}$)	Conversion Factor ($\Phi/c.s^{-1}$)
30	9.4×10^{-5}	2.5×10^{3}	3.8×10^{2}
60	2.6×10^{-5}	7.1×10^{2}	3.7×10^{2}
100	1.3×10^{-5}	3.1×10^{2}	4.1×10^{2}
150	8.4×10^{-4}	1.7×10^{2}	4.9×10^{2}

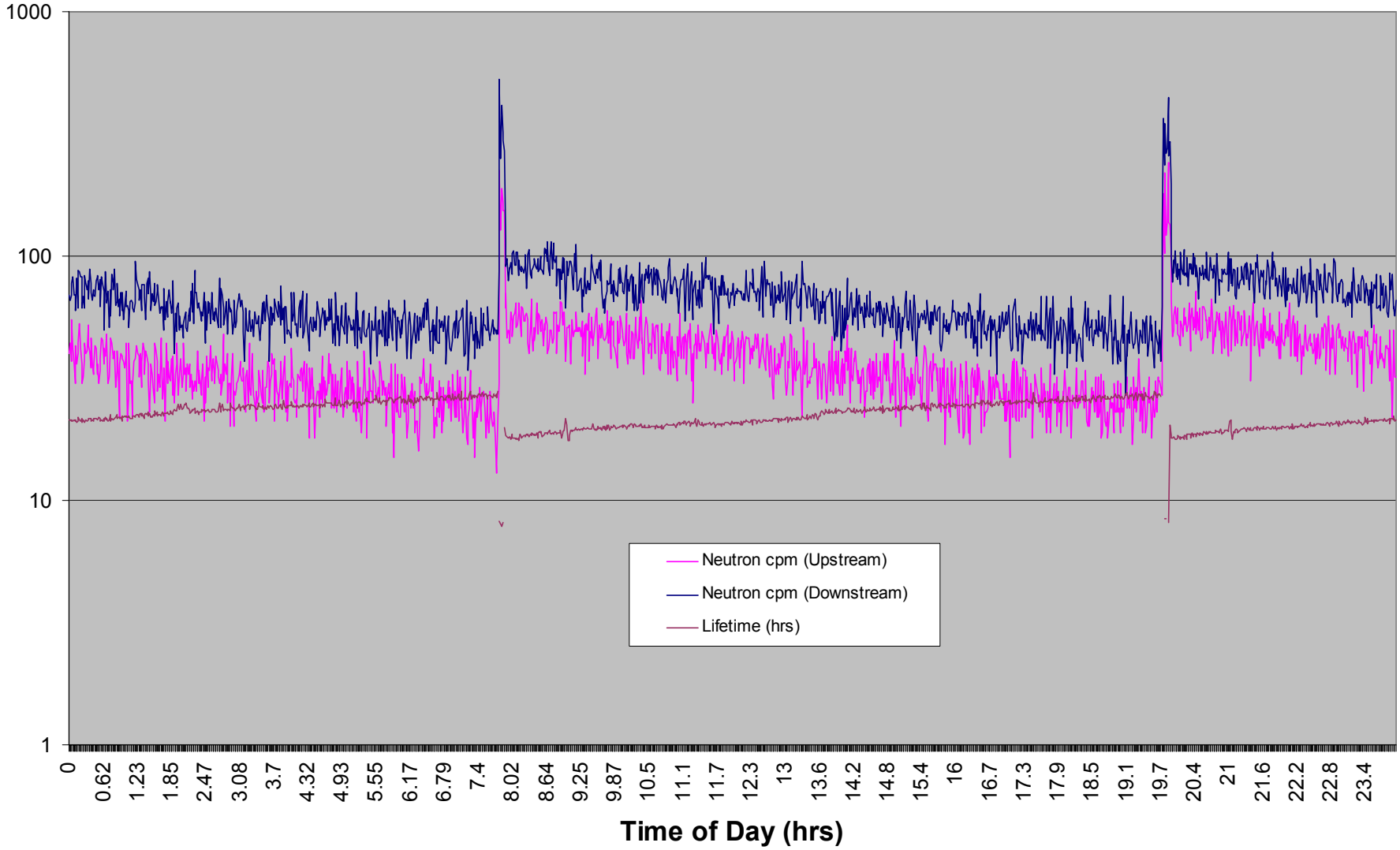
Calibration Results for Detector-Moderator Configuration Moderator Optimization (counts/s)

Distance from source	Bare detector	Detector with 3 cm poly.	Detector with 5 cm poly.	Detector with 7 cm poly.	Detector with 10 cm poly.
30 cm	13.6	1192	2510	3078	2428
60 cm	8.4	352	709	834	650
100 cm	7.0	161	302	345	271
150 cm	6.5	99	171	184	143

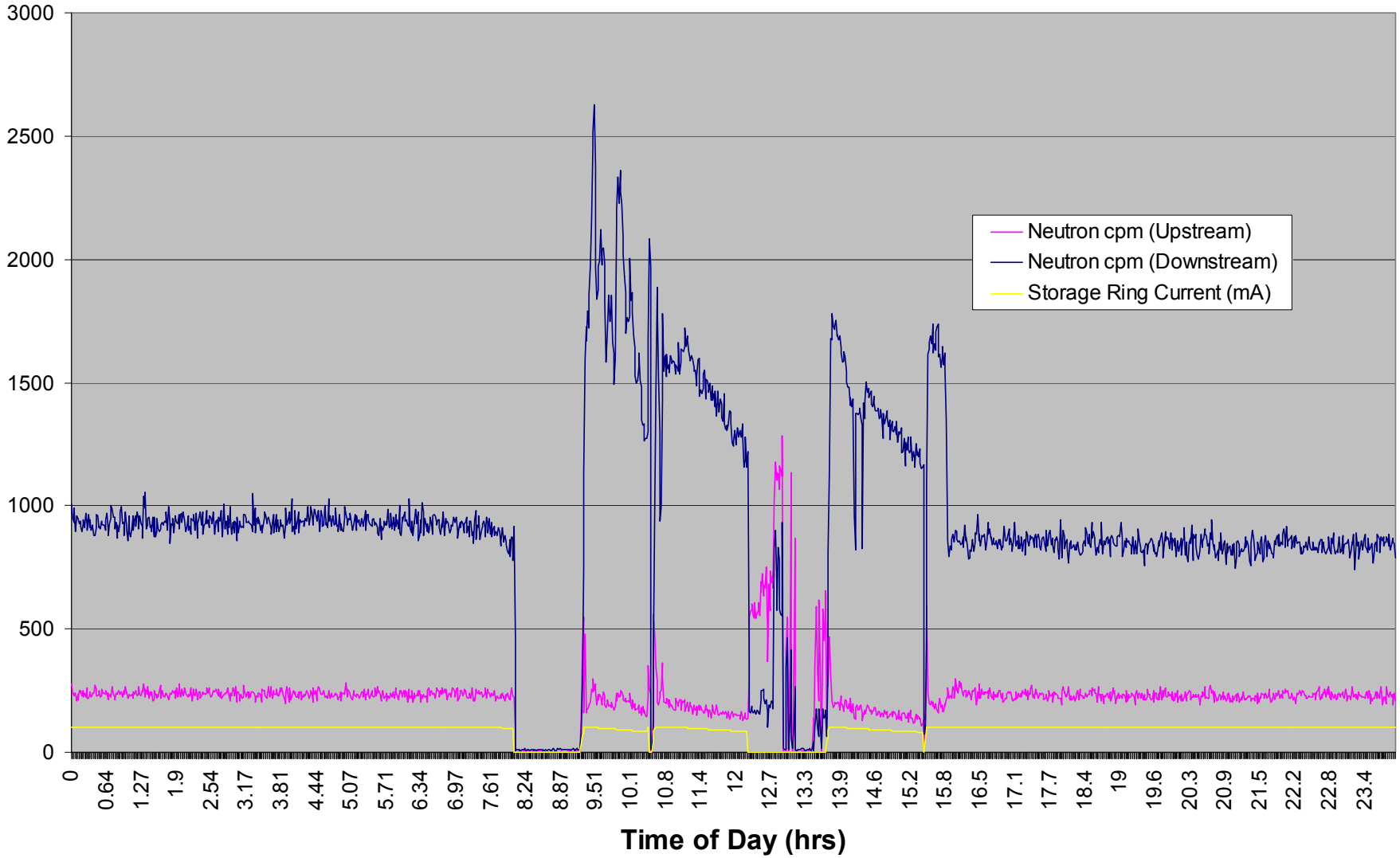
Neutron Detector Placement Inside the APS Storage Ring



Neutron Count Rate vs. Lifetime



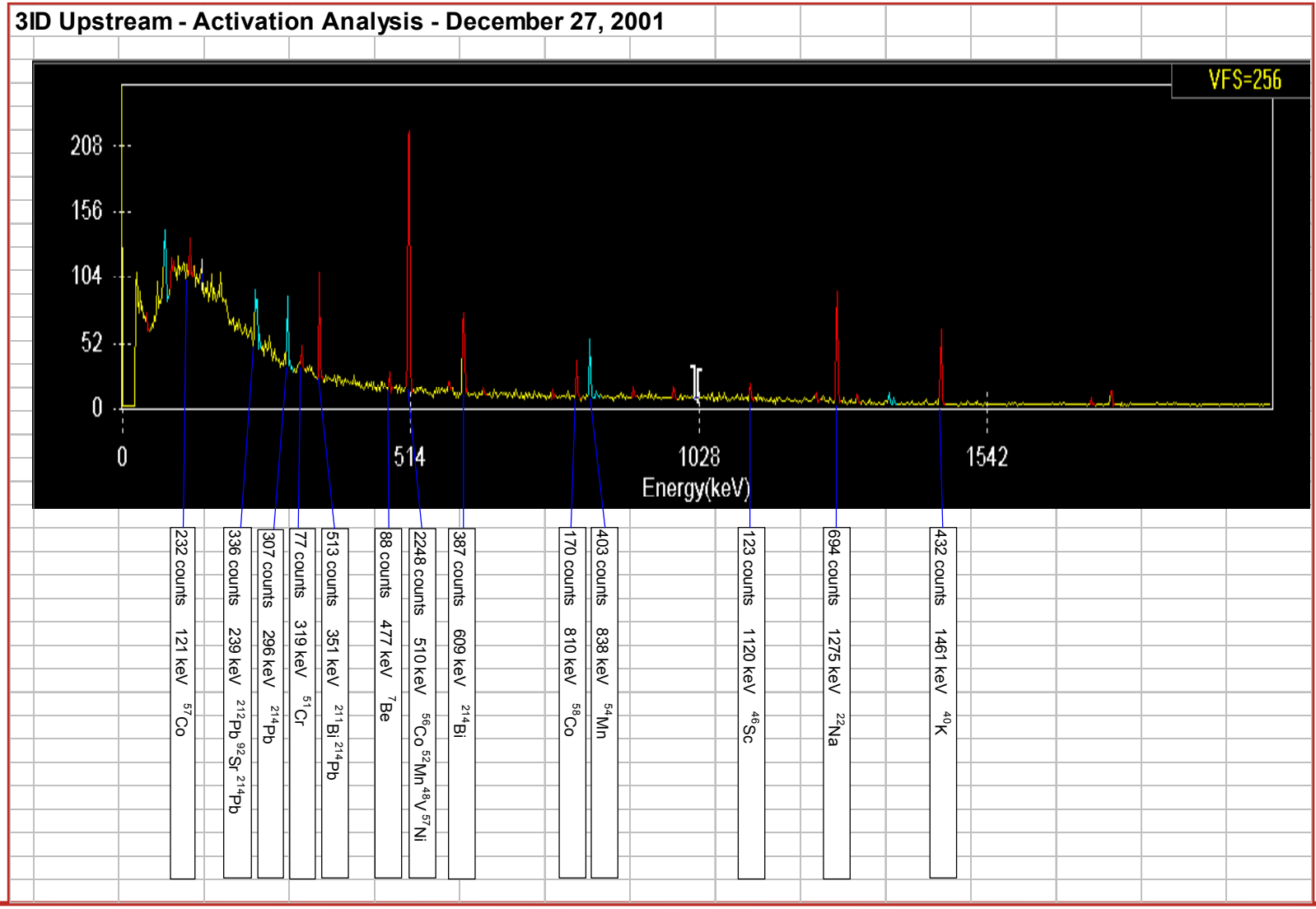
Neutron Count Rate vs. Operating Mode



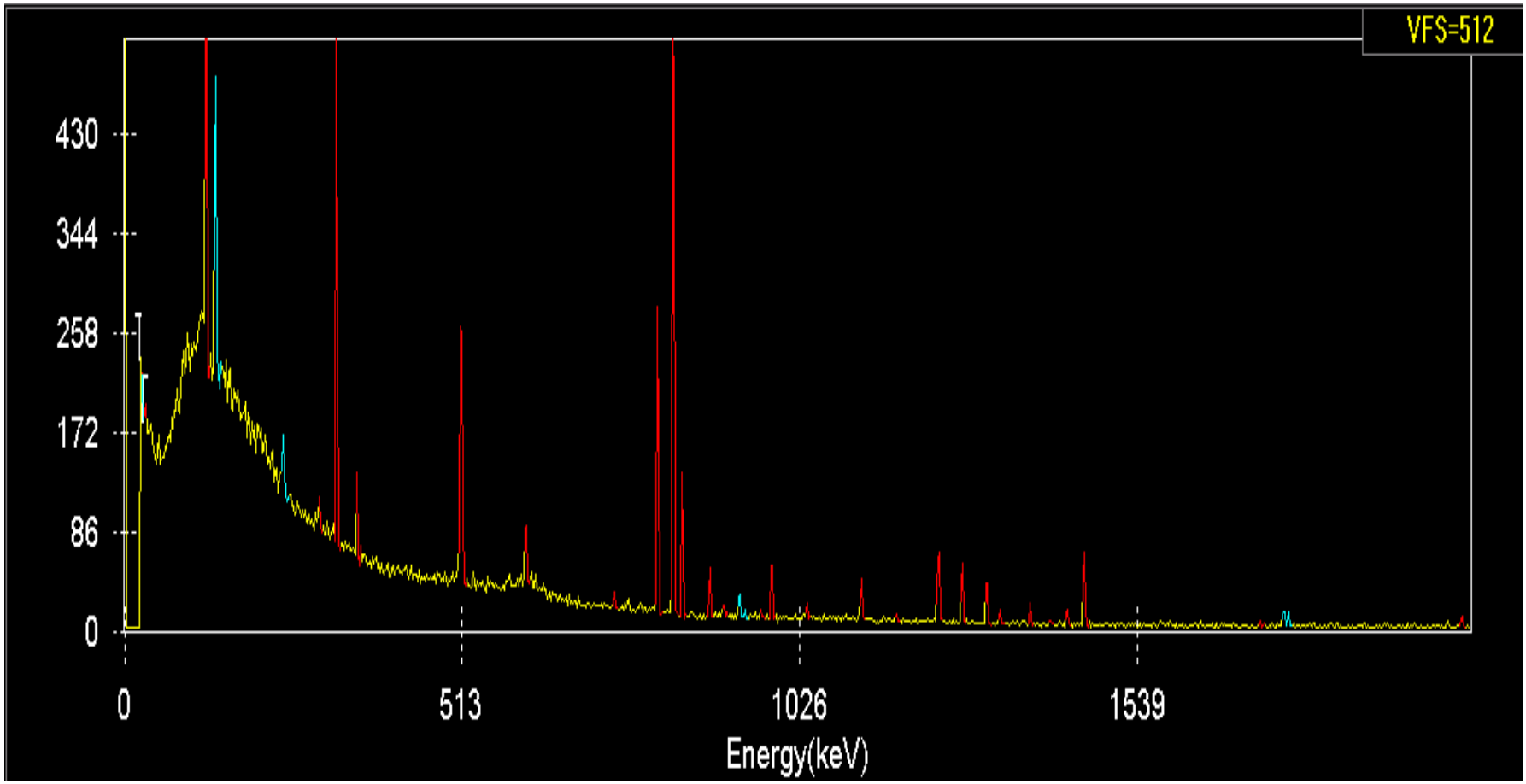
Storage Ring Activation Measurements

- Level of saturation activity during the run
- Activation elements at various locations
- Dose rates after the shut down and as a function of time

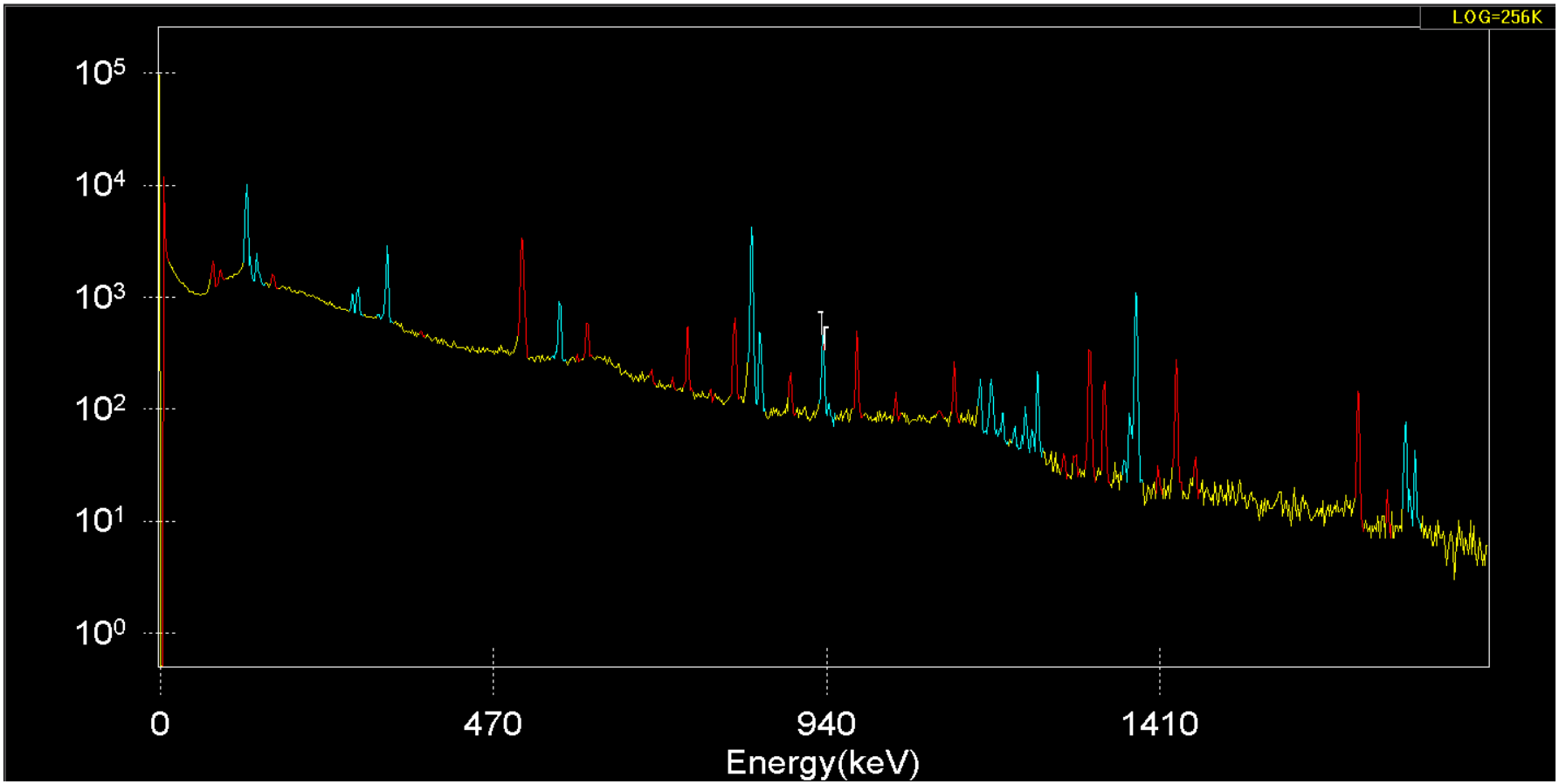
Activation Measurements of Accelerator Components (3 ID Upstream Box)



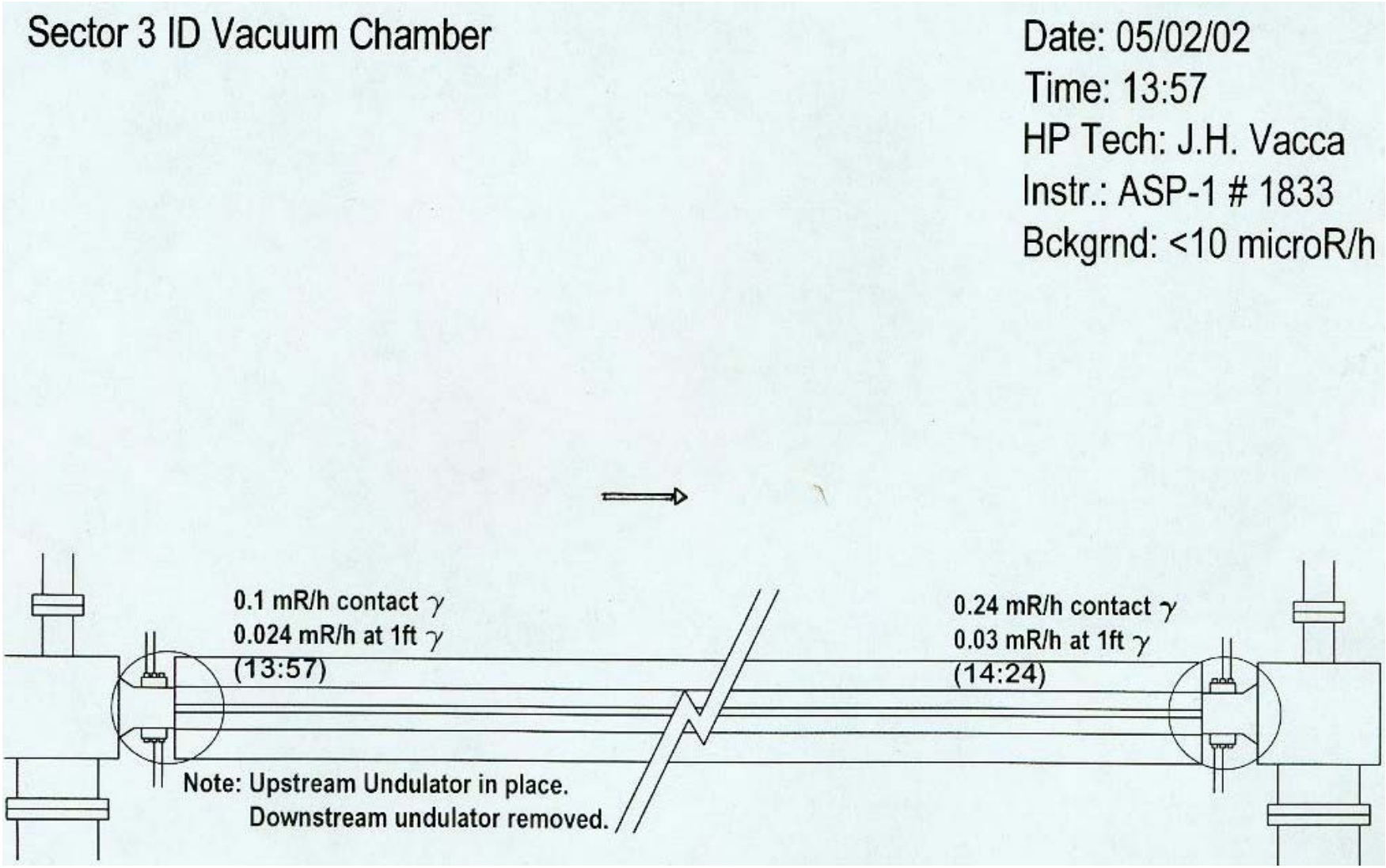
Activation Measurements of Accelerator Components (3 ID Downstream box)



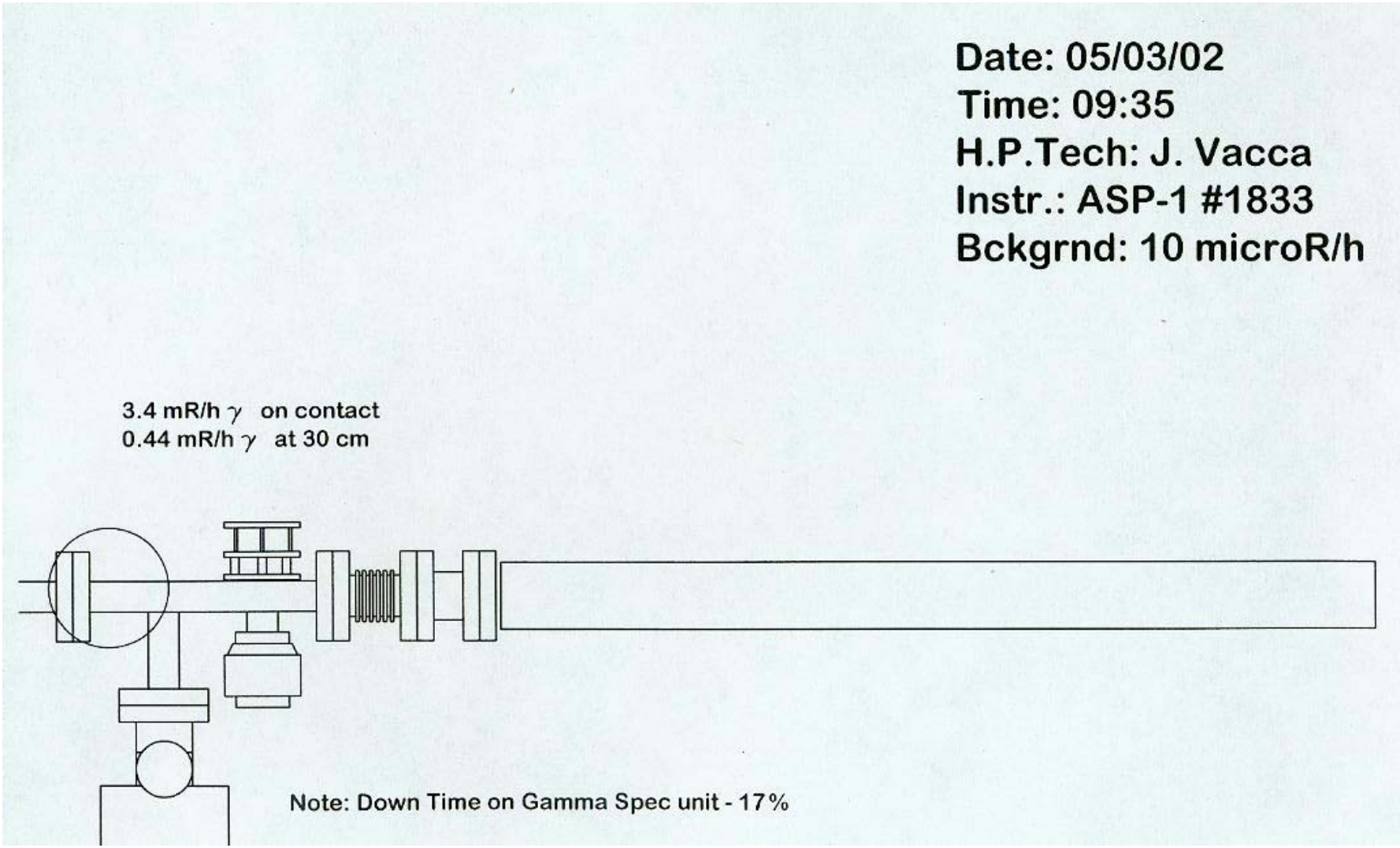
Activation Measurements of Accelerator Components (Booster Dump)



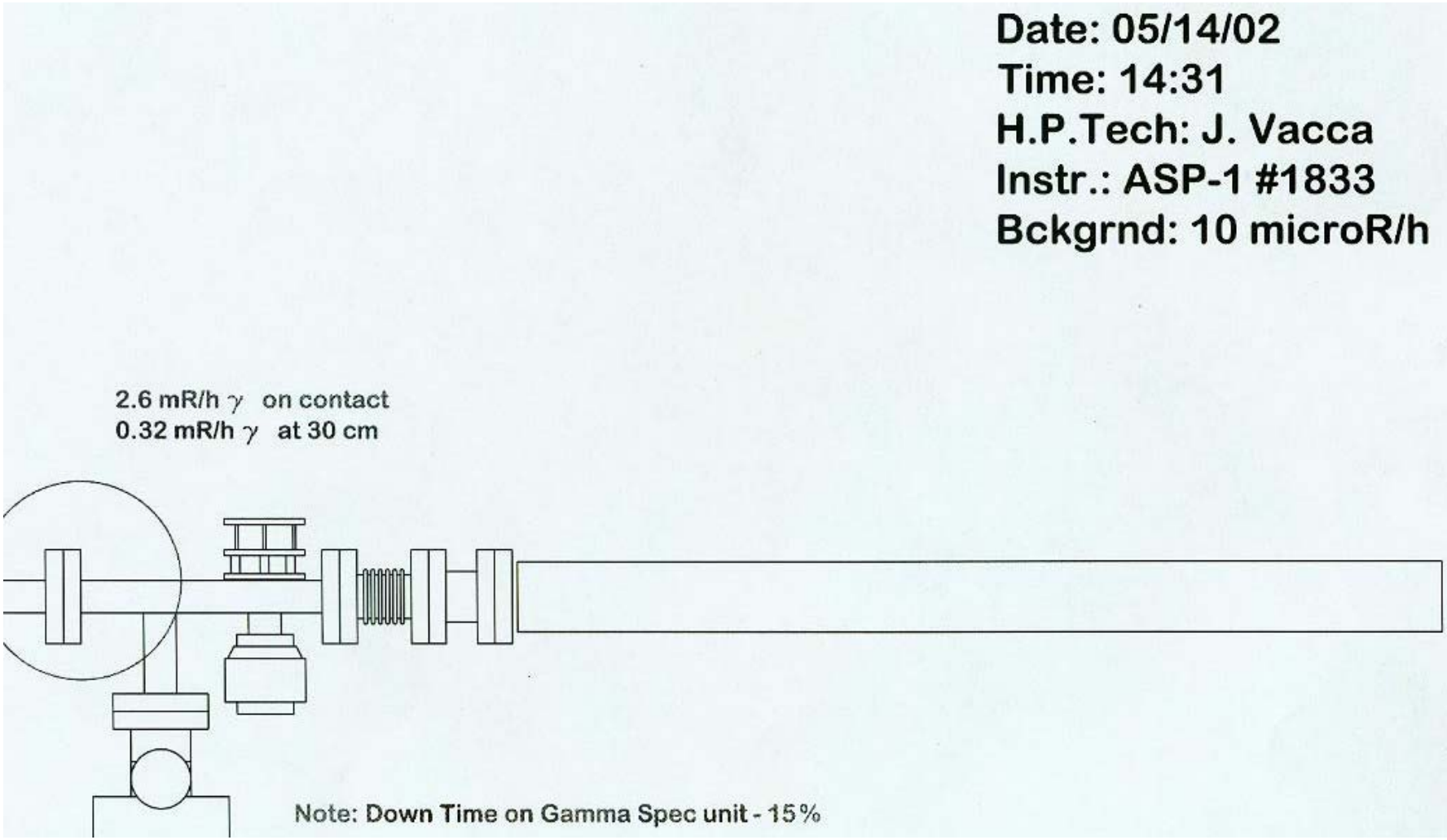
Dose Measurements of Accelerator Components (3 ID Straight Section)



Dose Measurements of Accelerator Components (Booster Dump



Dose Measurements of Accelerator Components (Booster Dump)



Dose Estimates due to Beam loss
MCNPX Simulation

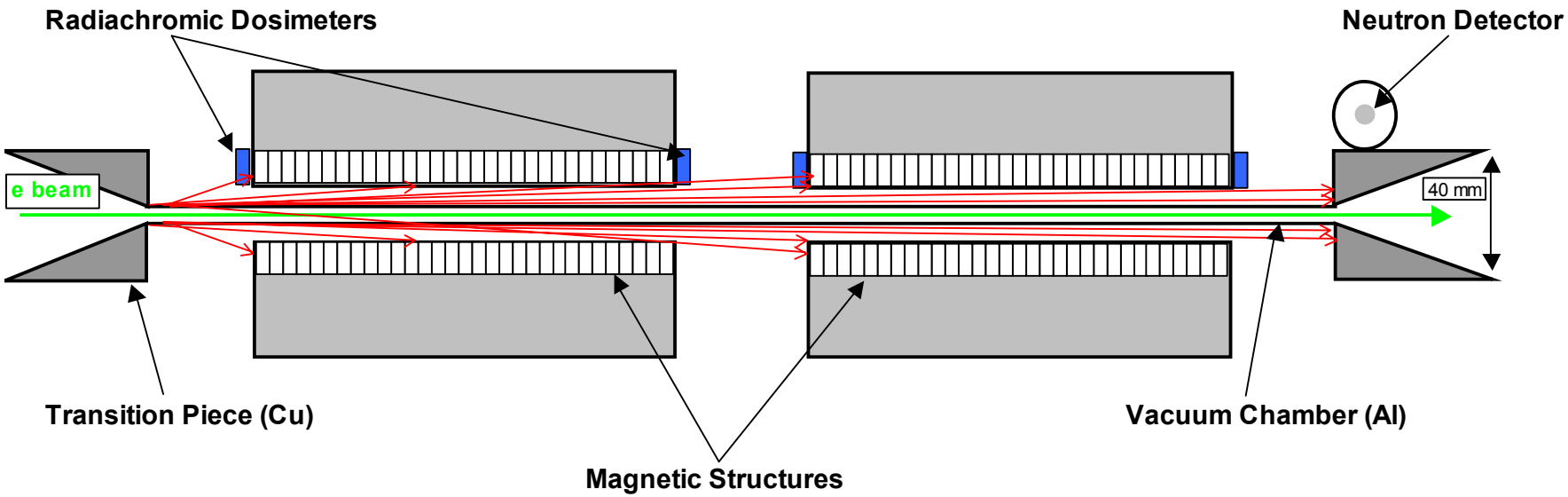
MCNPX Monte Carlo Program for Photons and Neutrons

- Models the interactions of radiation/matter for 34 particles
  - **Heavy ions are being added under NASA funding**
- Uses both table and model physics
  - **All standard and 150-MeV neutron, proton, photonuclear libraries**
  - **Photon, Electron physics (upto 1 GeV)**
  - **Bertini, ISABEL, CEM, INCL, and FLUKA**
- 3-Dimensional, continuous energy, fully time-dependent
- Supported on all UNIX, PC Windows, Mac G5
  - **Auto configuration, build system**
  - **FORTRAN90/95, dynamic allocation**
  - **Distributed memory parallel processing, PVM, MPI**

Dose Estimates due to Beam loss (MCNPX Simulation)

- Dose Estimates due to Different Beamloss Scenarios at the Straight Section
- Estimates of Photon Dose
- Estimates of neutron Dose
- Comparison with the measurements

MCNP Simulation - Calculational Geometry



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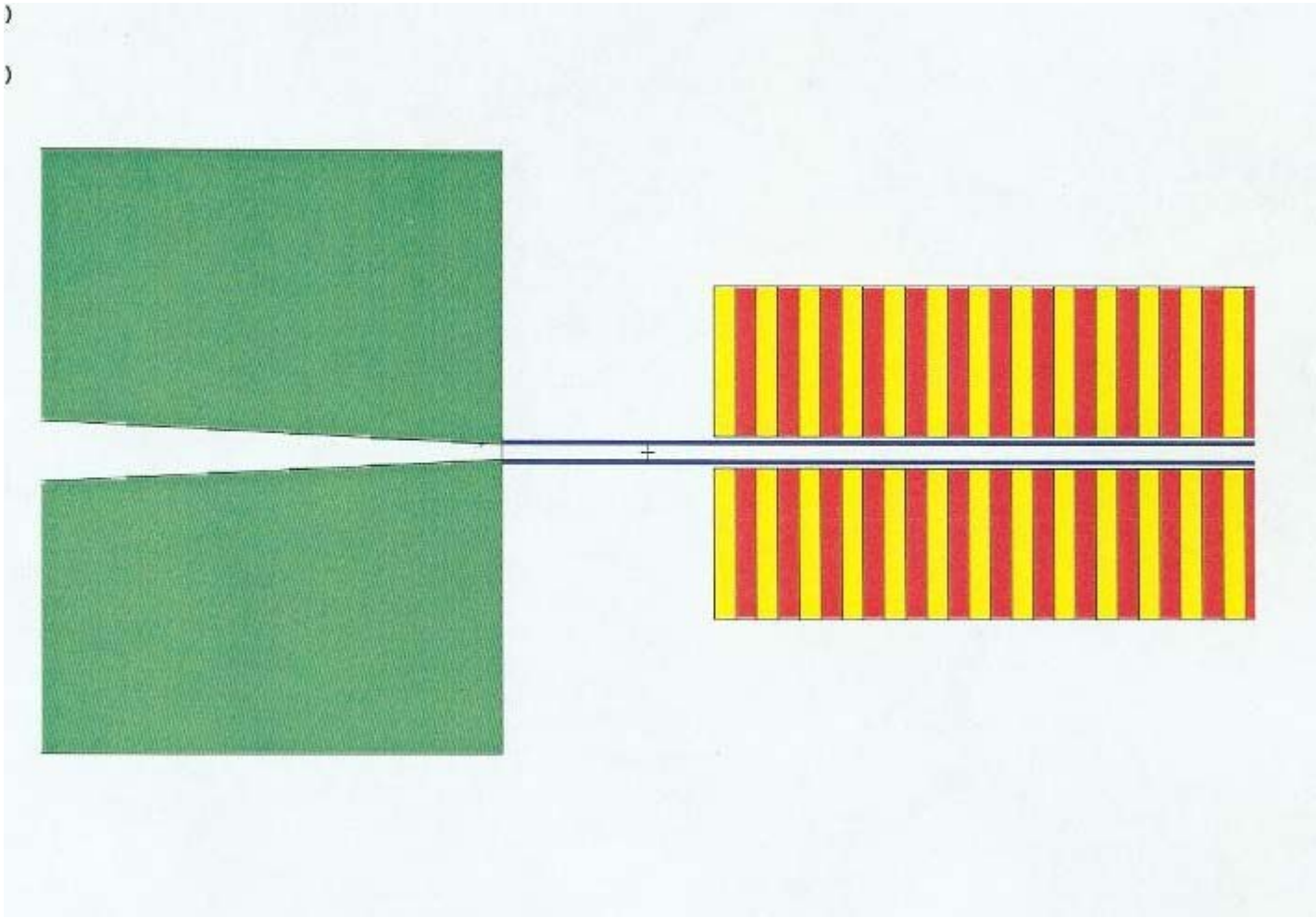

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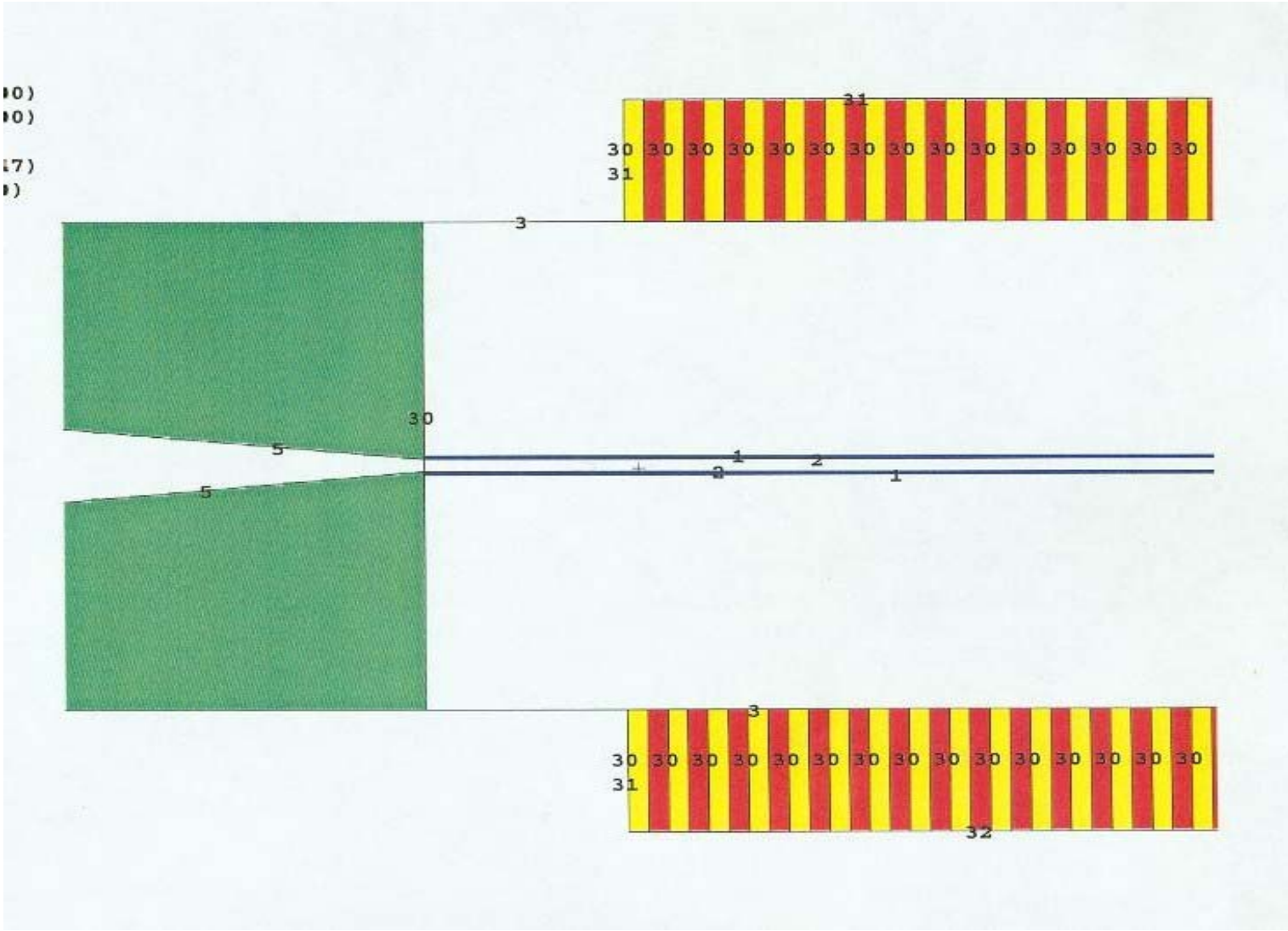
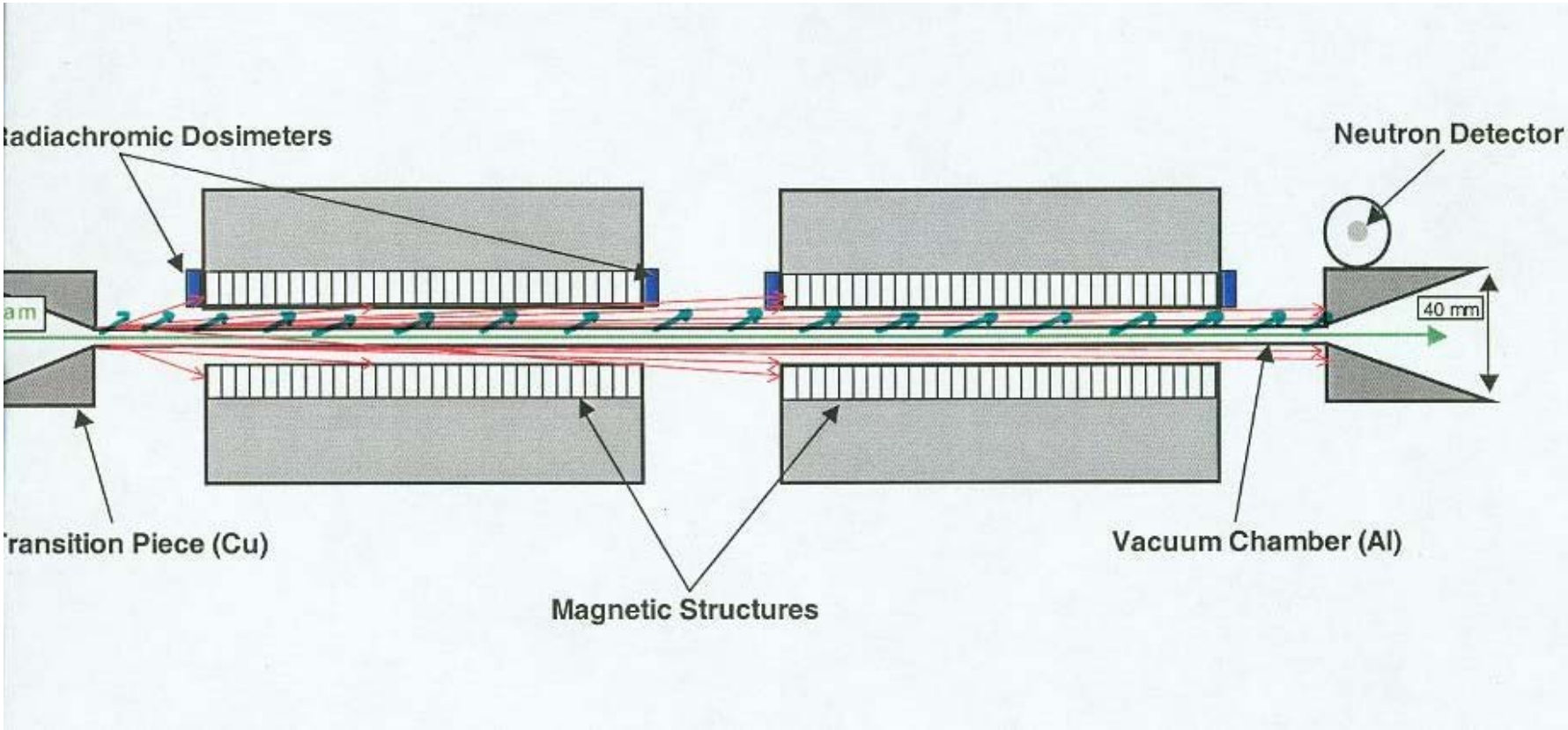
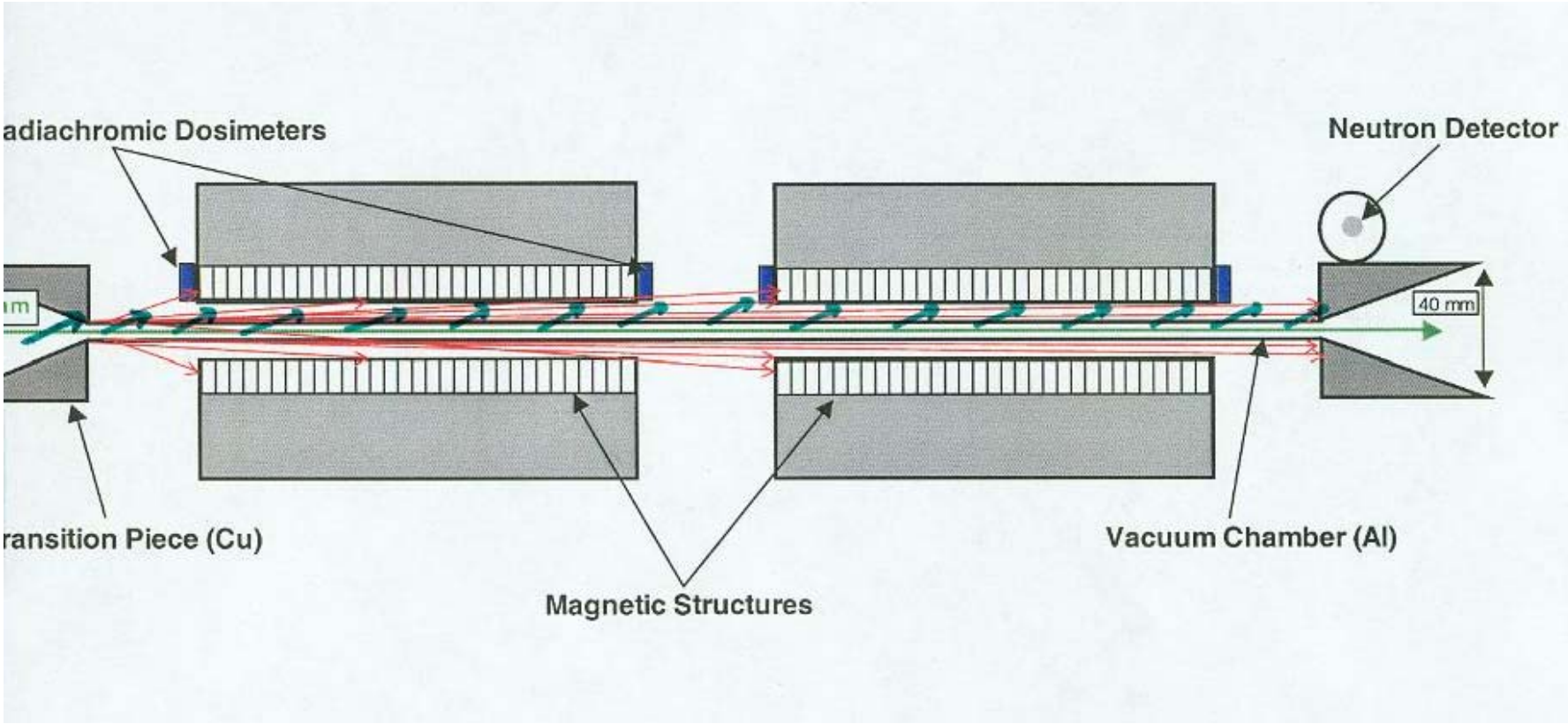


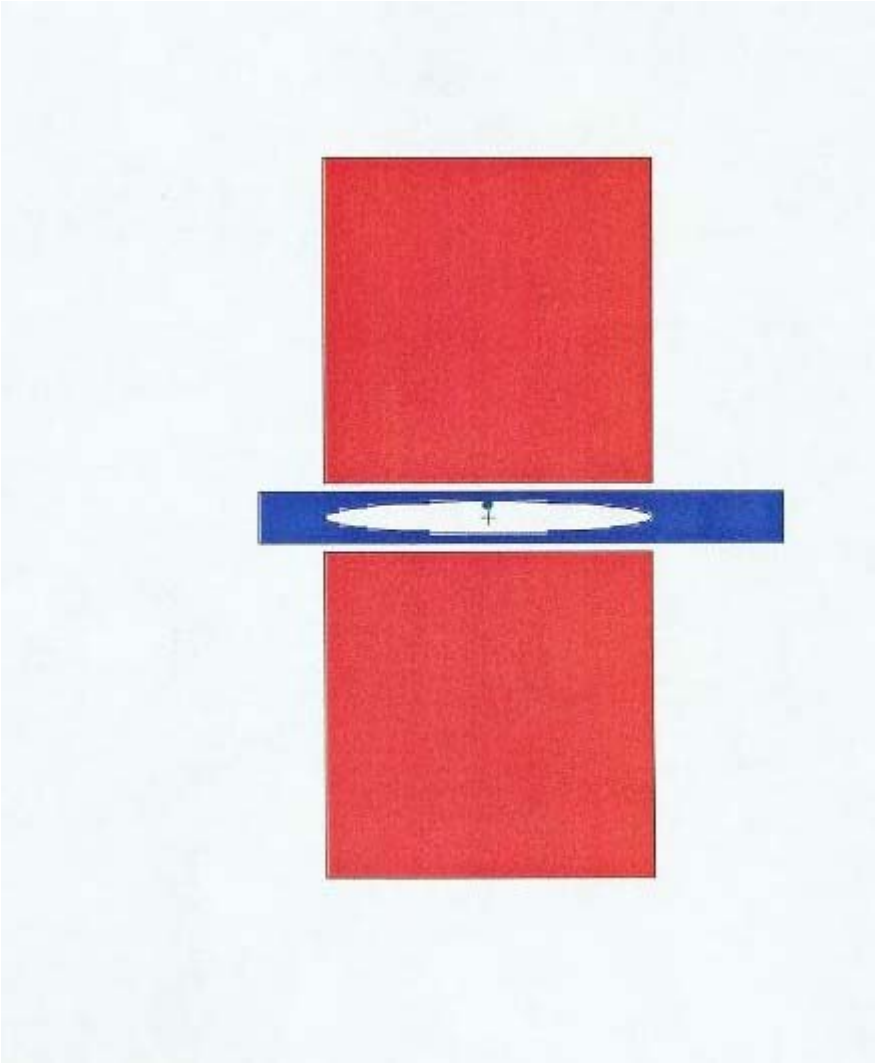
MCNP Simulation – Beamloss Scenario 1



MCNP Simulation – Beamloss Scenario 2

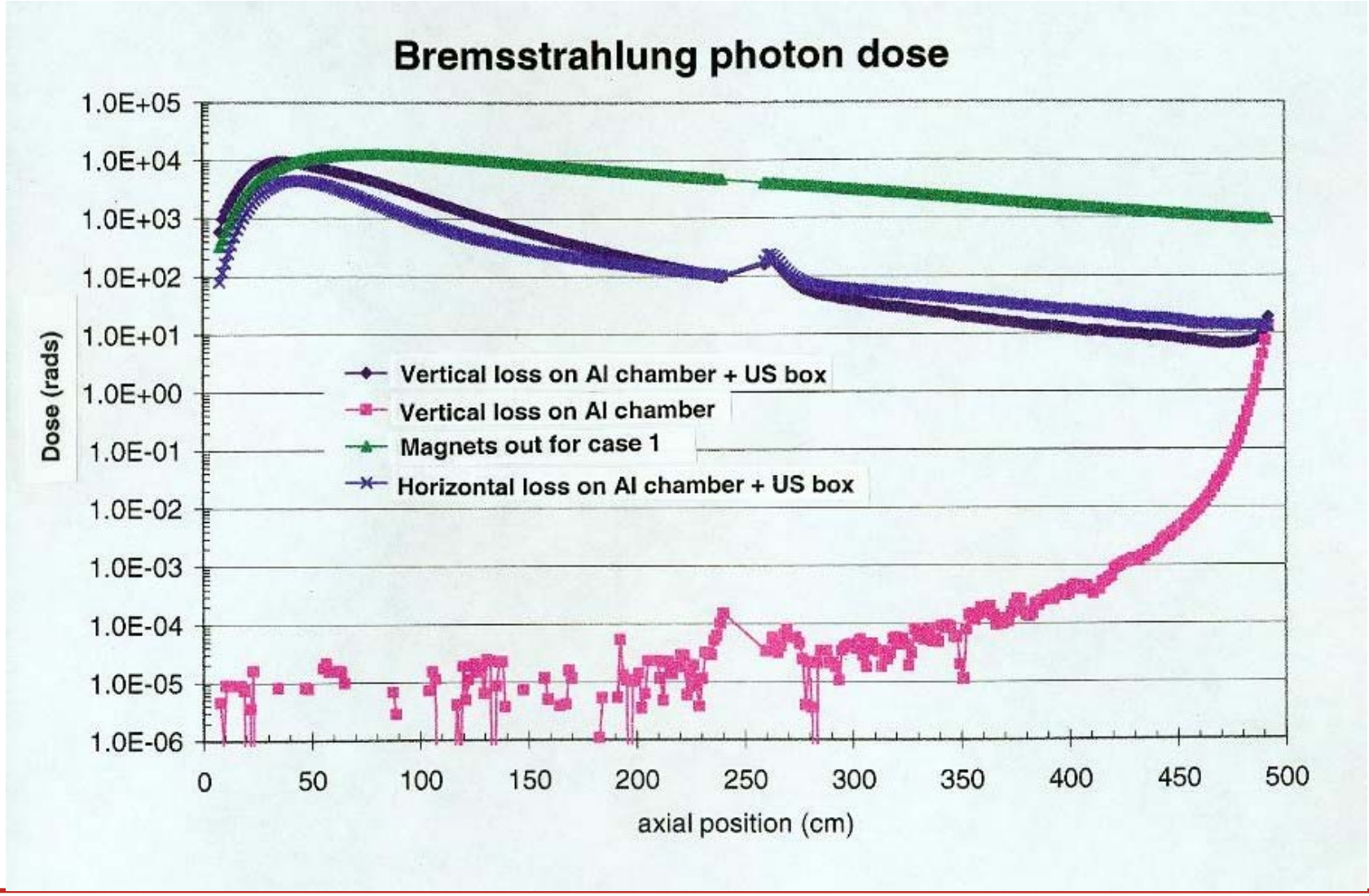


MCNP Simulation – Beamloss Scenario



MCNP Results for Photon Dose due to Beam Loss

Beam Loss = 10^{10} electrons



MCNP Results for Neutron Dose due to Beam Loss
Beam Loss = 10^{10} electrons